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USER'S MANUAL FOR SINGLE-SOURCE (CRSTER) MODEL

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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16. ABSTRACT The Single Source (CRSTER) Model is a steady-state, Gaussian plume dispersion model designed for point-source applications. It calculates pollutant concentrations for each hour of a year, at 180 receptor sites on a radial grid. The hourly concentrations are averaged to obtain concentration estimates for time increments of specified length, such as 3-hour, 8-hour, 24-hour, and annual. The model contains the concentration equations, the Pasquill-Gifford dispersion coefficients, and the Pasquill stability classes, as given by Turner. Plume rise is calculated according to Briggs. No depletion of the pollutant is considered. Technical details of the programming are presented with complete descriptions of data acquirements and output. Flow diagrams and source program listings, including subprograms, are given as well as input data forms. Three papers on application, sensitivity and validation of the model are included as appendices.

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FOR
SINGLE-SOURCE (CRSTER) MODEL

Monitoring and Data Analysis Division
Source Receptor Analysis Branch

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

July 1977

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Preface

This publication contains information on and the computer programs for the Single Source (CRSTER) Model which is based on Gaussian assumptions and is applicable to non-reactive pollutants emitted from well-defined point sources. The Single Source (CRSTER) Model is one of the atmospheric dispersion models on the User's Network for Applied Modeling of Air Pollution (UNAMAP) system. The UNAMAP system may be purchased on magnetic tape from NTIS for use on user's computer system, or UNAMAP may be accessed through phone lines and time-share computer terminals using a national teleprocessing network. For information on accessing UNAMAP contact: Chief, Environmental Applications Branch, Meteorology and Assessment Division, (MD-80), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

Although attempts are made to thoroughly check out computer programs with a wide variety of input data, errors are found occasionally. In case there is a need to correct, revise or update this model, revisions will be distributed in the same manner as this report. Revisions may be obtained as they are issued by completing the mailing form on page V. A user can be assured that the latest version of the Single Source (CRSTER) Model is on the UNAMAP system.

Comments and suggestions regarding this publication should be directed to: Chief, Source Receptor Analysis Branch, Monitoring and Data Analysis Division (MD-14), EPA, Research Triangle Park, NC 27711. However, technical questions regarding execution of the model may be handled by telephone call to the Chief, Modeling Support Section, Source Receptor Analysis Branch in Durham, NC at 919-541-5335 or, using FTS, 629-5335.

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Although many individuals assisted with time and energy in the preparation and review of this report, notwithstanding the extensive modification, testing and validation of thw basic model, the credits for truly significant contributions belong primarily to Russell F. Lee, Connally E. Mears, Jerome B. Mersch, Gerald K. Moss and Phillip L. Youngblood.

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I would like to receive future revisions to the *User's Manual for the Single Source (CRSTER) Model.*

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1. MODEL OVERVIEW

1.1 BACKGROUND AND PURPOSE

The Single Source (CRSTER) Model is a computer program designed to simulate atmospheric dispersion processes for the purpose of calculating ambient concentration levels of atmospheric contaminants. The model, originally known as MX24SP, was developed by the Meteorology Laboratory of the Environmental Protection Agency in 1972. Since that time numerous modifications and revisions have been added to the computer program to increase its utility. The purpose of this manual is to document fully the present version of the Single Source (CRSTER) Model computer program.

1.2 SCOPE AND USE

1.2.1 Applications

The Single Source (CRSTER) Model is appropriate for application to a wide variety of air pollution problems. It has been utilized primarily in simulating the behavior of stack effluents from combustion sources. Although designated as the *Single* Source (CRSTER) Model, the computer program offers the capability of considering up to 19 stacks simultaneously which are located at a common site.

The types of application for which the model is well-suited includes:

- Stack design studies
- Combustion source permit applications
- Regulatory variance evaluation
- Monitoring network design
- Control strategy evaluation for SIPs
- Fuel (e.g., coal) conversion studies
- Control technology evaluation
- Design of supplementary control systems
- New source review
- Prevention of significant deterioration

The model has been successfully applied previously to these types of problems. Additional uses will be developed as new issues arise.

1.2.2 Limits of Use

Successful application of the Single Source (CRSTER) Model is dependent on recognition of limitations imposed by mathematical assumptions associated with the model, the availability and form of meteorological data, and the structure of the computer program. The restrictions which these limitations impose may be categorized into source, pollutant, and meteorological factors.

Source factors which restrict the application of the model include a limitation to hot, bouyant stack plume emissions. In particular, the behavior of momentum-dominated plumes (i.e., cool, high velocity emissions) are not mathematically represented in the model. The model also does not simulate the behavior of plumes which are dominated by complex aerodynamic effects due to flow fields in the vicinity of the stack, nearby tall buildings or topographic features. Furthermore, only emissions from chimney stacks are simulated thereby eliminating ill-defined and/or fugitive type emission sources. Because the computer program considers all stacks at a plant to be co-located, significant physical separation of stacks can produce erroneous results. Consequently, stack emissions at other sites are not included in the computer program. Furthermore, the contribution to ambient pollutant concentrations from background sources is not included in the Single Source (CRSTER) Model; this must be handled separately.

The Single Source (CRSTER) Model does not consider gravitational effects and chemical transformation of plume constituents; neither does it incorporate any depletion mechanisms, e.g., rainout, washout and dry deposition. It assumes that the pollutants exhibit the dispersion behavior of non-reactive gasses.

The general types of meteorological data required as input to Single Source (CRSTER) Model can be classified as data on winds, temperature, mixing height, and sky conditions. The model is unique in this regard due to the last category. Sky condition parameters (i.e., sky cover and ceiling height) are routinely reported only by continuously manned meteorological stations. The input data base must, therefore, be in the proper format and the Preprocessor program (Section 1.4.1) is the most effective means to produce this.

1.3 BASIC DEFINITIONS AND CONCEPTS

1.3.1 Basic Definitions

- Air Pollutants - An air pollutant is a substance added to the atmosphere that causes a deviation from its mean composition and is present in sufficient quanitity to have an adverse effect. The types of pollutants that are commonly considered in dispersion modeling applications are those for which National Ambient Air Quality Standards (NAAQS) have been established. Currently these are sulfur oxides (SO_2), total suspended particulates (TSP), carbon monoxide (CO), non-methane hydrocarbons (HC), nitrogen dioxide (NO_2) and photochemical oxidants (O_x). SO_2 and TSP are emitted primarily by stationary sources, while transportation sources are the principal contributors to CO, HC and NO_2 emissions. O_x are not directly emitted, but are formed by chemical reactions in the atmosphere involving HC and NO_2 emissions and sunlight.
- Dispersion Model - A dispersion model is a mathematical description or representation of the meteorological transport and turbulent diffusion processes that occur in the atmosphere. Generally, such a model relates pollutant concentrations for specific receptors and averaging times to emissions from pollutant sources. This relationship is a function of meteorological conditions and the spatial relationship between sources and receptors. Thus the input data requirements for a dispersion model include: meteorological data, source data and receptor information.
- Stationary Pollutant Emission Sources - Stationary sources are those for which emissions can be identified with a plant or an area that remains geographically fixed. The principal emissions from stationary sources are due to external fuel combustion in boilers, industrial processing operations, and solid waste incineration.
- Point Sources - A point source is a large, identifiable stationary source causing emissions of any pollutant at a rate greater than a defined limit, e.g., 100 tons per year. For a given point source, the data required as input to a dispersion model are average emission rates, and physical stack parameters such as stack height, diameter, exit velocity and exit temperature.
- Receptors - A receptor is a point in space at which the ambient air quality is being determined. For a given receptor, the data required as input to a dispersion model are its coordinate location relative to that of the pollutant source.

- Averaging time - This is the time interval of specific length over which variations in pollutant concentration at a receptor are averaged. Because instantaneous concentrations at receptors exhibit wide temporal variations, time averaged concentrations provide a more convenient characterization of pollutant levels at a receptor. The averaging times for dispersion models are designed to be consistent with the NAAQS and commonly include the following: 1-hour, 3-hour, 8-hour, 24-hour, and annual averages.
- Meteorological Data - The meteorological data required for input to a dispersion model characterize the transport and turbulent diffusion properties of the atmosphere. The parameters which are commonly used to characterize these processes are: wind direction, wind speed, atmospheric stability and mixing height. Wind direction determines the direction of movement of the plume, i.e., its advection. Wind speed affects the initial dilution of the pollutant as it is emitted from the stack. Atmospheric stability determines the rate of turbulent diffusion of the plume as it moves downwind. Mixing height determines the depth of the atmosphere through which pollutants can be dispersed in the vertical. The National Weather Service (NWS) collects most data.
- Advection - Advection is the process of transport of an air parcel by the velocity field of the atmosphere. Advection is represented in the model by the azimuth direction of the wind.
- Diffusion - Diffusion in the atmosphere involves mass exchange between regions in space. Diffusion in the lower atmosphere is dominated by eddy exchange due to turbulent air movements, the magnitude of which is generally relatable to atmospheric stability.
- Turbulence - Turbulence is a state of fluid flow in which the instantaneous velocities exhibit irregular and apparently random fluctuations, and can in practice only be described by statistical properties.
- Atmospheric Stability - Stability is an atmospheric property which characterizes the thermodynamic structure of the atmosphere in terms of sustaining disturbances. Stability is commonly defined by comparison of the actual temperature lapse rate with the "dry adiabatic" lapse rate and can be broadly classified into classes of stable, neutral, and unstable.

1.3.2 Concepts

The Single Source (CRSTER) Model presents a specific set of input data requirements, and yields output data consisting of pollutant concentrations for a specific averaging time and receptor location. The input data requirements can be broadly classified as source factors, site factors, and meteorological factors. Source factors are related to the location and operating characteristics of the pollutant emission sources, while site factors include the effect of terrain and the location of sensitive receptors relative to the emission sources. Meteorological factors represent the dispersion properties of the lower atmosphere at any particular time in terms of the joint occurrence of specific conditions of atmospheric stability, mixing depth, and winds.

The Single Source (CRSTER) Model is composed of two parts, namely, a plume rise model for estimating the effective release height of the pollutant plume from a point source, and a diffusion model to calculate the downwind dispersion of the plume. Both of these mathematical models attempt to represent the actual processes that occur in the atmosphere, under a simplifying set of assumptions.

The rise of an emission plume above its source height often accounts for a significant reduction in related ground-level concentrations. A submodel in the Single Source (CRSTER) Model calculates the rise of hot, buoyant plumes under varying meteorological conditions. Representation of the transport and turbulent diffusion of a source plume is accomplished by a Gaussian plume model. This model provides a representation of the time-averaged spatial distribution of pollutant concentrations downwind of a continuously emitting point source. The rate of expansion of the plume is characterized by a series of empirical dispersion coefficients which are functions of atmospheric stability and downwind distance from the source.

1.4 SYSTEM DESCRIPTION

1.4.1 Preprocessor Program

The preprocessor program is executed independently and prepares meteorological data in the tape input format required by the Single Source (CRSTER) Model. The basic function of this program, as shown by the schematic in Figure 1-1, is to transform surface and upper air meteorological information obtained from the National Climatic Center (NCC). The operations performed by this program include:

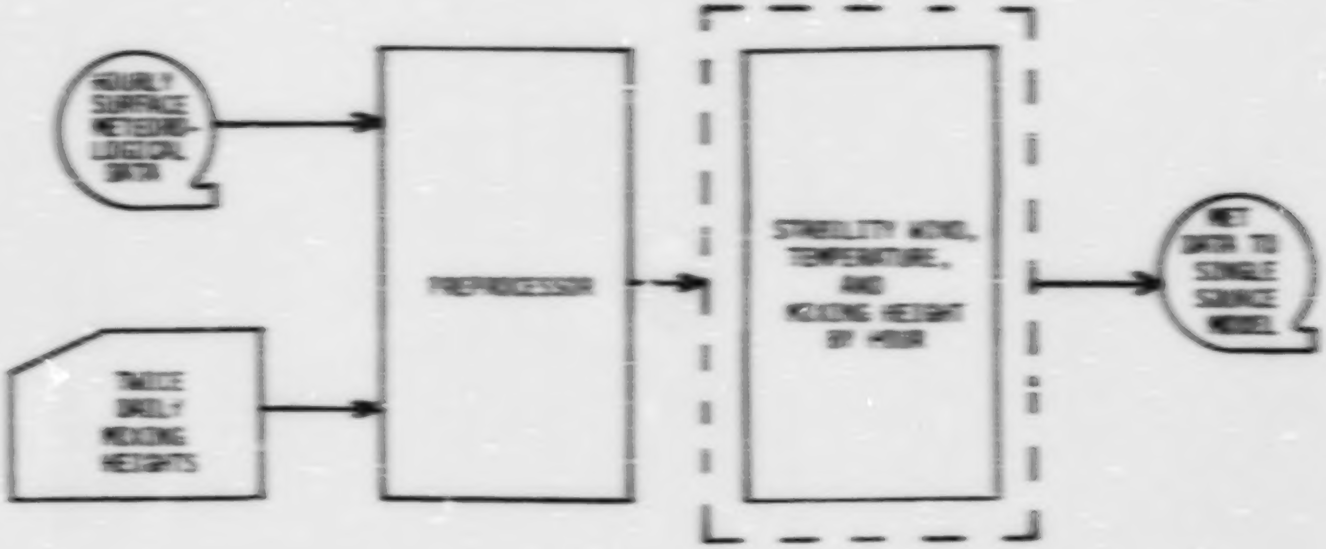

HOURLY SURFACE METEORO-LOGICAL DATA
TWICE DAILY MIXING HEIGHTS
PREPROCESSOR
STABILITY WIND, TEMPERATURE, AND MIXING HEIGHT BY HOUR
MET DATA TO SINGLE SOURCE MODEL

FIGURE 1-1

SCHEMATIC OF METEOROLOGICAL DATA PREPROCESSOR

- Calculate hourly values for atmospheric stability from meteorological surface observations,
- Interpolate twice daily mixing height data to hourly values,
- Reformat other meteorological data to be compatible with Single Source (CRSTER) Model input requirements.

A detailing of the methodologies employed is presented in Section 2.3.

1.4.2 Single Source (CRSTER) Model

A functional schematic of the Single Source (CRSTER) Model is presented in Figure 1-2. As shown in this schematic, the model accepts the preprocessed meteorological data tape directly as input, as well as emission source, receptor site terrain, and program control specifications data. The program produces printouts and an optional tape of estimated concentrations. Details of the methodologies employed are presented in Section 2.2.

1.5 SUMMARY OF INPUT DATA

1.5.1 Preprocessor Program

The input data requirements for the Preprocessor program consist of two categories of meteorological data - hourly surface observations and twice daily upper air observations. Hourly surface observation data used are:

- Wind direction
- Wind speed
- Dry bulb temperature
- Sky cover
- Cloud ceiling height

These data can be obtained by request from the NCC by specifying a magnetic tape of hourly surface observations in card deck 144 format for the specific year of analysis and surface observation stations.

Daily upper air observation data input to the Preprocessor are:

- Early morning mixing height
- Afternoon mixing height

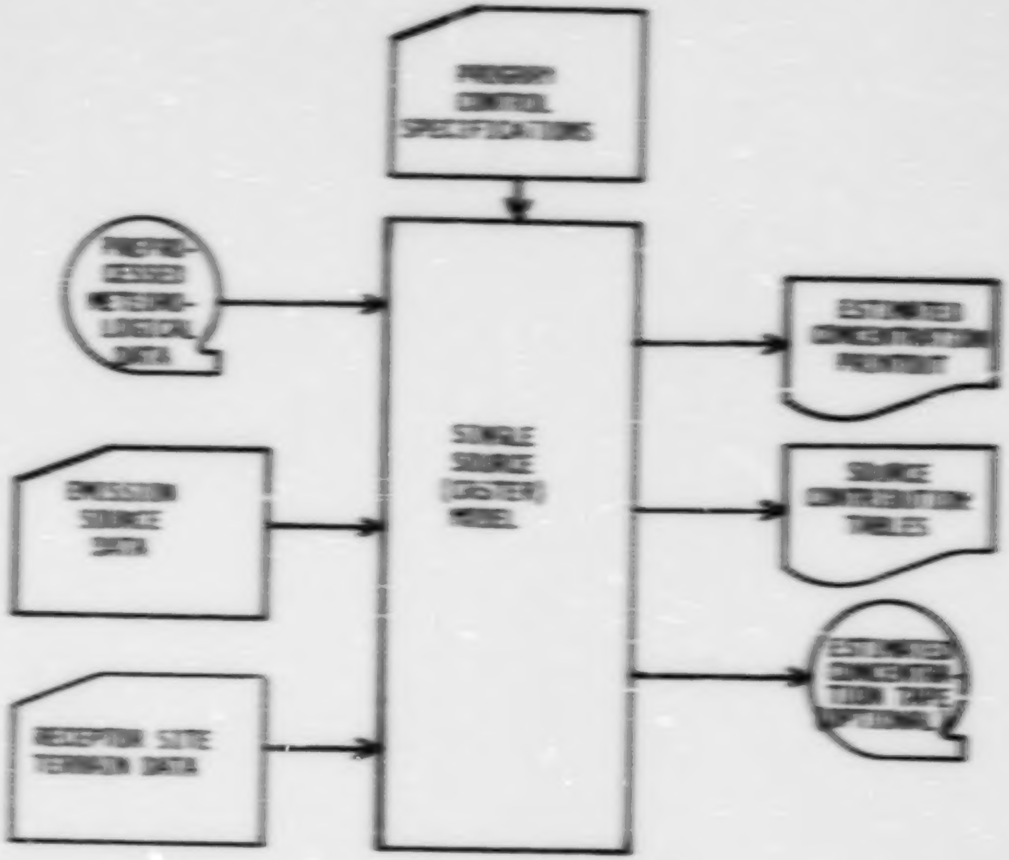

PROGRAM CONTROL SPECIFICATIONS
PREPRO-CESSED METEORO-LOGICAL DATA
EMISSION SOURCE DATA
RECEPTOR SITE TERRAIN DATA
SINGLE SOURCE (CRSTER) MODEL
ESTIMATED CONCENTRATION PRINTOUT
SOURCE CONTRIBUTION TABLES
ESTIMATED CONCENTRA-TION TAPE (OPTIONAL)

FIGURE 1-2

SCHEMATIC OF THE SINGLE SOURCE (CRSTER) MODEL

The mixing heights are based on NWS upper air soundings at 1200 GMT and 0000 GMT, respectively. These data also can be obtained by request from the NCC in either magnetic tape or tabular form by specifying "twice daily mixing heights" for the specific year of analysis and upper air observation stations.

The surface and upper air stations should be selected for their meteorological representativeness of the general area being modeled. Generally this corresponds to the stations closest to the point sources being modeled and in the same climatological regime (e.g., coastal, mountainous, plains). Meteorological data from 1964 are frequently used as input to the Single Source (CRSTER) Model, although data from any year can be obtained as long as surface data for each hour are available. The year 1964 is convenient because it is the last and most recent year for which routinely reported surface observations are transcribed by NWS on an hourly basis for data analysis purposes. Although NWS stations still report observations on an hourly basis on WBAN form A, only every third hour is keypunched for computer entry and this is not adequate for the Single Source (CRSTER) Model. Thus, there is a significant increase in the cost of obtaining a magnetic tape of hourly surface observations from the NCC for the years subsequent to 1964.

The output of the Preprocessor consists of hourly values of wind speed, flow vector, randomized flow vector, stability class, mixing heights and ambient temperature. The flow vector is numerically the 180° complement of the meteorological wind direction.

1.5.2 Single Source (CRSTER) Model

The input data requirements for the Single Source (CRSTER) Model consist of four categories of data:

- Meteorological
- Receptor site
- Source emissions
- Program control parameters

Each of these data categories is discussed separately below.

a. Meteorological Data. All meteorological data required by the Single Source (CRSTER) Model are contained on the magnetic tape output by the Preprocessor.

b. Receptor Site Data. The Single Source (CRSTER) Model estimates concentrations for each hour at a circular field of 180 receptors, defined by: (1) five downwind ring distances and (2) 36 radials (one for every 10° of azimuth). Although the 36 azimuths are fixed, selection of the five ring distances is made by the user and warrants judicious consideration since the choice of locations for receptor sites can significantly affect the concentration estimates.* Once the ring distances have been chosen, terrain elevations for the receptor coordinates can be obtained from topographic USGS quandrangle maps of the area (scale 1:24,000) available from the U.S. Geological Survey, Washington, D.C. 20242.

c. Source Emissions Data. The emission parameters required by the Single Source (CRSTER) Model for each point source are:

- Source elevation
- Average stack parameters, for each stack
  - pollutant emission rate
  - stack gas exit velocity
  - stack gas temperature
  - stack exit diameter
  - physical stack height

If desired, monthly instead of annual average values can be specified for the pollutant emission rate, stack gas exit velocity and stack gas temperature. The Single Source (CRSTER) Model permits data for up to 19 different point sources to be input, but considers all of them to be at the same geographic location.

---

*First approximations for the receptor ring distances can be made with the aid of the PTMAX program (see Section 2.5).

d. Program Control Parameters and Options. Program Control input data required by the Single Source (CRSTER) Model consist of parameters which direct the execution of the program and the use of optional model features. All control parameters have automatic default values (see Section 4.3.3.a), except for the urban/rural indicator which must be specified.

- Urban/Rural Indicator - this parameter specifies whether rural or urban mixing heights are to be used in the model calculations. For the urban case, only unstable and neutral stability conditions are considered, i.e., stable conditions are calculated as if neutral below the mixing height lid.
- Output Tape Indicator - this parameter specifies whether a magnetic tape of all hourly calculated concentrations is to be output.
- Elevation Indicator - this parameter specifies whether the point sources and receptors are located in flat or uneven terrain.
- Day Indicators - these parameters identify days of the year for which concentrations are to be calculated.
- Meteorological Output Indicator - this parameter specifies whether the hourly meteorological data used in the model calculations will be printed out.
- Variable Averaging Time - this parameter specifies the optional concentration averaging times available in the model calculations.
- Monthly Emissions Indicator - this parameter specifies whether average monthly emission rates will be input for each point source.
- Monthly Stack Gas Exit Velocity Indicator - this parameter specifies whether monthly stack gas exit velocities will be input for each point source.
- Monthly Stack Gas Temperature Indicator - this parameter specifies whether monthly stack gas temperatures will be input for each point source.
- Source Contributions Indicator - this parameter specifies whether separate source contribution tables will be printed out in lieu of concentration tables.

1.6 MODEL OUTPUT

The output generated by the Single Source (CRSTER) Model can be classified into the following four categories:

- Printouts of input data
- Printouts of concentration tables

: Printouts of source-contributions
: Magnetic tape of calculated concentrations

The type of output produced under each of these categories is described briefly below and in more detail in Section 4.3.4.a.

Printouts of the input data by the model include the source emission information, meteorological data for each day concentrations are calculated, receptor elevation data, and program control parameters and options.

The concentration tables printed out by the model include tables for each averaging time of the highest and second-highest concentrations at each receptor point, and tables of the 50 highest concentrations for the entire year for each averaging time (except the annual).

One optional output of the model is the form of a magnetic tape of all 1-hour pollutant concentrations calculated during a given model execution. Another optional output of the model is printouts of the source-contributions of individual point sources to up to 20 receptor points for each averaging period, in lieu of concentration tables.

2. TECHNICAL DISCUSSION

2.1 SINGLE SOURCE (CRSTER) MODEL FORMULATION

The Single Source (CRSTER) Model is designed to calculate the contributions from multiple elevated stack emissions at a single plant location to ambient air quality levels, defined in the same time scales as the National Ambient Air Quality Standards. The program calculates concentrations for an entire year and prints out the highest and second-highest 1-hour, 3-hour and 24-hour, as well as annual mean concentrations at a set of 180 receptors surrounding the plant. The Single Source (CRSTER) Model is based on a modified form of the Gaussian plume equation which uses empirical dispersion coefficients and includes adjustments for plume rise, limited mixing height and elevated terrain. Pollutant concentrations are computed from measured hourly values of wind speed and direction, and estimated hourly values of atmospheric stability and mixing height. This chapter discusses the technical basis for the model as currently formulated.

2.2 METEOROLOGICAL DISPERSION ASSUMPTIONS

The Single Source (CRSTER) Model is based on a modified version of the Gaussian plume equation. This model assumes a continuous emissions source, steady-state downwind plume, and a Gaussian distribution for concentrations of pollutants within the plume in both the crosswind and vertical directions. Plume rise is estimated using equations proposed by Briggs [1-3] for hot, buoyant plumes. As the plume expands due to eddy diffusion, it is diluted and transported downwind by the mean wind. The rate of expansion is characterized by a series of empirical dispersion coefficients which are dependent on the stability of the atmosphere, as determined in studies made by Pasquill [4] and Gifford [5], and reported by Turner [6,7]. The modifications made to the basic Gaussian plume equation in the Single Source (CRSTER) Model include the following:

- Trapping of the plume between the top of the mixing layer and the ground surface,

- Uniform vertical mixing of the plume in the mixing layer beyond a critical distance;
- Exclusion of any ground-level impacts from plumes released above the mixing layer.

Each of the above factors are discussed separately in the sections below.

2.2.1 The Gaussian Plume Equation

The Gaussian plume equation for a continuous emission source gives the local concentration χ of a gas or aerosol at a ground-level location (x,y) by the following expression:

$$\chi\ (x,y) = \frac{Q}{\pi\ \sigma_y \sigma_z\ u}\ \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad (2\text{-}1)$$

where the wind is advecting the plume at a speed u along the x-axis and dispersing it along the crosswind and vertical direction with diffusion coefficients σ_y and σ_z, respectively. The pollutant emission from the source is at a uniform rate Q and is assumed to be released at an "effective stack height" H (see Section 2.2.5). It is assumed that complete reflection of the plume takes place at the earth's surface, i.e., there is no atmospheric transformation or deposition at the surface (see Section 2.2.6). The concentration χ is an average over the time interval represented by σ_y and σ_z. The Single Source (CRSTER) Model calculates short-term concentrations and uses these directly as 1-hour average concentrations without consideration of plume history, i.e., each 1-hour period is completely independent. Equation (2-1) is valid for any consistent set of units, however those commonly employed are χ in $(g\ m^{-3})$, Q in $(g\ s^{-1})$, u in $(m\ s^{-1})$, and x, y, H, σ_y and σ_z in (m).

2.2.2 Basic Assumptions

The Gaussian plume equation (2-1) is a solution to the simplified conservation of mass equation assuming nonzero wind speed and constant eddy diffusivities along the principal axes. The use of a single wind speed and constant direction in the Gaussian plume equation reflects the assumption that the horizontal wind field is homogeneous, and that the effects of directional wind shear in the atmospheric boundary layer are not considered. The effects of surface friction in reducing wind speeds near ground-level are taken into account, however, by the Single Source (CRSTER) Model (see Section 2.2.4).

The assumptions incorporated in the Gaussian plume equation and the Single Source (CRSTER) Model can be summarized as follows:

- Steady-State Conditions - ideal gas, continuous uniform emission rate, homogeneous horizontal wind field, representative hourly mean wind velocity, no directional wind shear in the vertical, infinite plume, no plume history.
- Pollutant Characteristics - the pollutant emitted is a stable gas or aerosol which remains suspended in the air and participates in the turbulent movement of the atmosphere, none of the material is removed as the plume advects and diffuses downwind and there is complete reflection at the ground.
- Gaussian Distribution - the pollutant material within the plume takes on a Gaussian distribution in both the horizontal crosswind and vertical directions, described by empirical dispersion parameters σ_y and σ_z.

2.2.3 Dispersion Coefficients

The empirical dispersion coefficients, σ_y and σ_z, used in the Single Source (CRSTER) Model are those suggested by Pasquill [4] and Gifford [5], and reported by Turner [6,7]. Values for σ_y and σ_z are represented as a function of downwind distance from the emissions source and the stability of the atmosphere. These values are representative for a sampling time of up to about one hour and were developed based on aerometric measurements taken in open, level to gently rolling country. Implementation of these parameters in the Single Source (CRSTER) Model is accomplished by using piecewise equations (dependent on stability) which approximate the dispersion curves between specific downwind distances.

Atmospheric stability is determined indirectly from the amount of incoming solar radiation at the surface (insolation), and the wind speed. Pasquill suggested a six category classification scheme from A for extremely unstable to F for moderately stable, based on the range of these two parameters. Because solar radiation is not a widely measured parameter, Turner [6] developed an objective classification method based on cloud cover, ceiling height, and solar elevation (see Section 2.3.2). The Single Source (CRSTER) Model Preprocessor calculates the stability classification by this method for each hour from the recorded meteorological observations.

2.2.4 Wind Speed Determination

The wind speed required for input to the Single Source (CRSTER) Model is considered to be representative of the conditions throughout the vertical height interval in which the plume is dispersing. The wind at the stack elevation is commonly used as an approximation to this condition. Because the wind is generally measured near 7 meters by the National Weather Service (NWS), an adjustment is made in the model by the following power law relationship:

$$u = u_0 \; (h/7)^p \qquad (2\text{-}4)$$

where

u = hourly wind speed at stack height (m s^{-1})
u_0 = hourly wind speed near 7m above the ground (m s^{-1})
h = stack height (m)
p = wind profile exponent

The profile exponent p is a function of stability and has the values given in Table 2-1. The adjusted wind speed is used by the model to calculate plume rise and dilution.

2.2.5 Effective Stack Height - Plume Rise

The effective height of emission (H) used in the Gaussian plume equation (2-1) is defined as the sum of the physical stack height (h_s) and the plume rise (Δh). Estimates of plume rise are required to predict

TABLE 2-1

WIND SPEED PROFILE EXPONENT

Pasquill Stability Class	Wind Speed Profile Exponent, P
A = extremely unstable	0.10
B = moderately unstable	0.15
C = slightly unstable	0.20
D = neutral	0.25
E = slightly stable	0.30
F = moderately stable	0.30

the dispersion of continuous gaseous emissions possessing buoyancy. The rise of emission plumes above their source release height often accounts for a significant reduction in related ground-level concentrations.

Plume rise in the Single Source (CRSTER) Model is estimated using equations proposed and later modified by Briggs [1,2,3]. These equations are based on the assumption that plume rise depends on the inverse of the mean wind speed and is directly proportional to the 2/3 power of the downwind distance from the source, with different equations specified for the neutral-unstable conditions and the stable conditions. Only the final plume rise as predicted by Briggs is used in the Single Source (CRSTER) Model. Briggs' plume rise equations are detailed below, where all symbols are defined in Table 2-2.

- For unstable or neutral atmospheric conditions, the downwind distance of final plume rise is $x_f = 3.5\ x^*$, where

$$x^* = 14\ F^{5/8}, \text{ when } F < 55\ m^4\ s^{-3} \qquad (2\text{-}5)$$

$$x^* = 34\ F^{2/5}, \text{ when } F \geq 55\ m^4\ s^{-3}. \qquad (2\text{-}6)$$

The final plume rise under these conditions is

$$\Delta h = 1.6\ F^{1/3}\ (3.5\ x^*)^{2/3}\ u^{-1}. \qquad (2\text{-}7)$$

- For stable atmospheric conditions, the downwind distance of final plume rise is $x_f = \pi\ u\ s^{-1/2}$, where

$$s = g\ \partial\theta/\partial z\ T^{-1}. \qquad (2\text{-}8)$$

The plume rise is

$$\Delta h = \begin{cases} 2.4\ [F/(u\ s)]^{1/3}, & \text{for windy conditions} \qquad (2\text{-}9) \\ 5\ F^{1/4}\ s^{-3/8}, & \text{for near-calm conditions} \qquad (2\text{-}10) \end{cases}$$

For the final plume rise under these conditions, the smaller of the values estimated by (2-9) and (2-10) is used.

TABLE 2-2

DEFINITION OF SYMBOLS USED IN BRIGGS' PLUME RISE EQUATIONS

[illegible]	Definition	Units
g	gravitational acceleration	$9.8\ m\ s^{-2}$
d	stack inside diameter at top	m
F	buoyancy flux parameter $[g\ v_s\ (d/2)^2\ (T_s - T/T_s)]$	$m^4\ s^{-3}$
x^*	distance at which atmospheric turbulence begins to dominate entrainment	m
Δh	plume rise above stack top	m
x	downwind distance from the source	m
T	ambient air temperature	°K
T_s	stack gas temperature	°K
u	mean wind speed from stack top to plume top	$m\ s^{-1}$
v_s	stack gas exit velocity	$m\ s^{-1}$
$\partial\theta/\partial z$	vertical potential temperature gradient from stack top to plume top	$°K\ m^{-1}$
s	restoring acceleration per unit vertical displacement for adiabatic motion in the atmosphere, a stability parameter	s^{-2}

The final plume rise given by these formulae does not take cognizance of "negative" buoyancy due to cold plumes, or aerodynamic effects from flow fields around the stack or nearby tall buildings and prominent terrain. The final plume height used by the Single Source (CRSTER) Model does not follow changes in terrain height,as described further in Section 2.4.

2.2.6 Limited Mixing

Turbulent mixing and vertical diffusion of a plume is often limited by the existence of a stable layer of air aloft, i.e., an inversion layer. The effects of limited mixing (or plume "trapping") on plume dispersion are incorporated into the Single Source (CRSTER) Model by the assumption that the plume is completely reflected at the mixing height (L), as well as the ground. Since multiple reflections are possible as shown in Figure 2-1, trapping is simulated using the method of multiple images proposed by Bierly and Hewson [8]. In this procedure, each reflection is represented by an "image plume" from an imaginary source with a "stack height" equal to the vertical distance travelled by the plume "edge" to the point of ground reflection. The reflections between the mixing height (L) and the ground can be represented by the convergent infinite series of Gaussian plume terms given in Equation (2-11), see Table 2-3. Several simplifications are used in the Single Source (CRSTER) Model in implementing this concept. Because the infinite series in Equation (2-11) converges rapidly, the summation is limited to the sum of -k to +k terms until the additional contribution of the next two terms [-(k+1) and (k+1)] is less than 0.01 sm^{-3}. This means the relative concentration is calculated as a sum of a series of terms. When the addition of the next term in the series contributes to an increase of less than 0.01, the summation is stopped. In any case, k is limited to a maximum of 45. Also beyond the downwind distance where $\sigma_z = 1.6\,L$, such reflections result in a nearly uniform vertical distribution of concentration. Thus, an appropriate simplification is introduced in the computations, see Equation (2-12). Another assumption is that whenever the plume centerline (H) is above the mixing height (L) at a given receptor location, there is no contribution from the plume at that receptor.

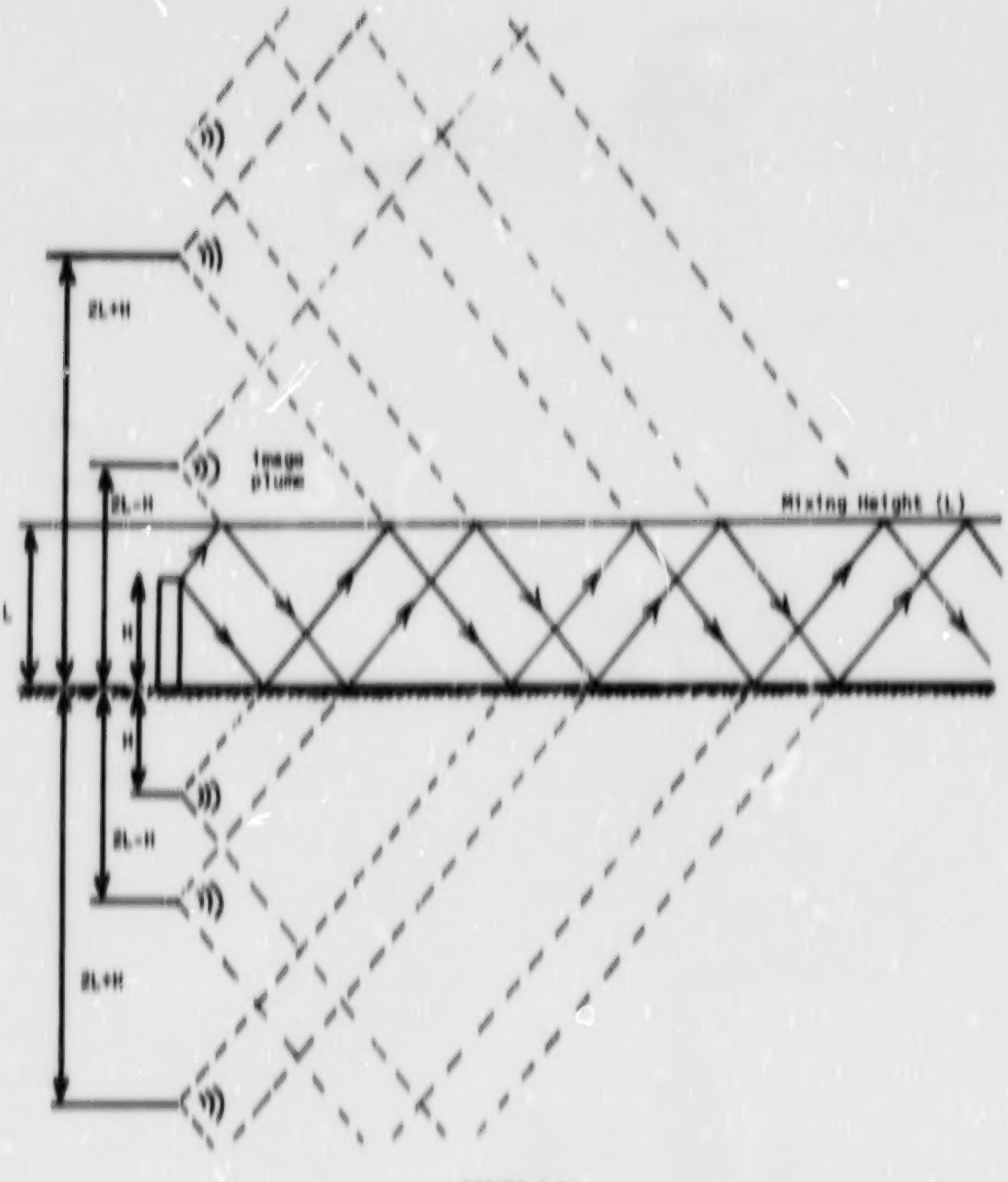

2L+H
Image
plume
2L-H
Mixing Height (L)
L
H
H
2L-H
2L+H

FIGURE 2-1

THE METHOD OF MULTIPLE PLUME IMAGES USED TO SIMULATE PLUME REFLECTIONS IN THE SINGLE SOURCE MODEL

TABLE 2-3

MODIFIED GAUSSIAN PLUME EQUATIONS USED IN THE SINGLE SOURCE (CRSTER) MODEL

If $H \leq L$ and $\sigma_z \leq 1.6L$
$$\chi = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \sum_{N=-\infty \atop (-k)}^{\infty \, (+k)} \exp\left[-\frac{1}{2}\left(\frac{H+2NL}{\sigma_z}\right)^2\right] \quad (2\text{-}11)$$

If $H \leq L$ and $\sigma_z > 1.6L$
$$\chi = \frac{Q}{\sqrt{2\pi}\, \sigma_y L u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \quad (2\text{-}12)$$

If $H > L$
$$\chi = 0 \quad (2\text{-}13)$$

Hourly values of the mixing height, for both rural and urban regimes, are estimated by the Preprocessor program by the method described in Section 2.3.1. The Single Source (CRSTER) Model assumes the mixing height is constant above any receptor location whose elevation is above plant base elevation and below the top of the stack. Terrain adjustments are discussed in detail in Section 2.4.

2.2.7 Treatment of Wind Direction and Relation to Receptor Network

The Single Source (CRSTER) Model calculates pollutant concentrations for a radial network of 180 receptor points, as shown in Figure 2-4. This array consists of five downwind distances along each 10° azimuth direction (see Section 2.5). The Single Source (CRSTER) Model calculates concentrations at these receptor points relative to the azimuth wind direction as determined by the Preprocessor program. This wind direction includes a random variation (-4 to +5°) superimposed on the value recorded by the NWS. Off-centerline concentrations are computed for those receptors which fall within the stability-dependent widths as defined in Figure 2-2. For example, under extremely unstable conditions (Class A), off-centerline concentrations are computed up to ±60° from the plume centerline, whereas for very stable conditions (Class F), the concentrations are calculated only to ±20°. The computation of off-centerline concentrations requires a value for the lateral distance of the receptor (y) in Equation (2-1). This value is estimated by the arc length along the ring for the angular difference between the randomized wind direction and the receptor azimuth. Thus,

$$y \cong \text{arc}^{*} = r\,(\alpha - \theta) \qquad (2\text{-}14)$$

where

r = ring distance of receptor point
θ = azimuth of receptor point
α = azimuth of randomized wind direction.

Concentrations at off-centerline receptors within the limits illustrated in Figure 2-2 are computed except when the exponential y term in Equation (2-1) is essentially zero, i.e., less than 2×10^{-22}.

* The difference between using arc length and straight line is quite small.

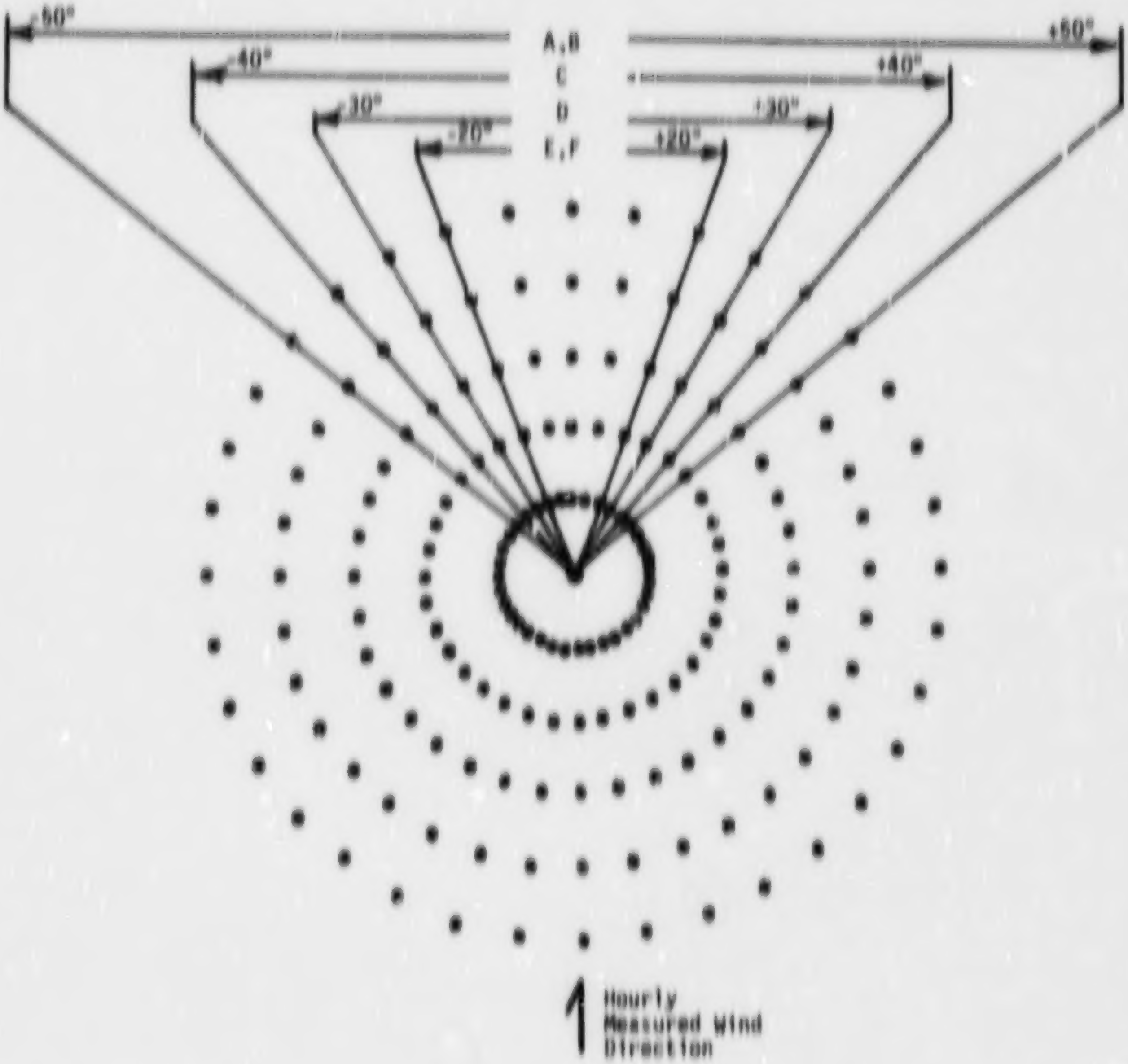

-50°
A,B
+50°
-40°
C
+40°
-30°
D
+30°
-20°
E,F
+20°
Hourly
Measured Wind
Direction

FIGURE 2-2

EXAMPLE OF RECEPTOR NETWORK USED IN THE SINGLE SOURCE (CRSTER) MODEL FOR A SOUTH WIND AND FOR EACH STABILITY CLASS

2.2.8 Urban-Rural Considerations

The principal difference between dispersion coefficients in rural and urban environments is associated with the occurrence of the nocturnal, ground-based temperature inversion. On calm, clear nights, radiational cooling can produce such an inversion, and hence stable atmospheric conditions, in a rural environment. Such inversions do not occur, though, in urban areas, due primarily to the influence of a city's larger surface roughness and the release of stored heat from structural surfaces, i.e., the urban heat island effect. Thus, stable atmospheric conditions do not occur near the ground in urban areas on calm, clear nights.

The Single Source (CRSTER) Model accounts for these effects in both the choice of dispersion coefficients and mixing heights. If an urban application is indicated, stability categories E and F default to category D for the purpose of determining σ_y and σ_z (see Section 2.3.2). Separate sets of hourly mixing height data, for urban and rural environments, are input to the model and it chooses between these, depending on the conditions indicated (see Section 2.3.1).

2.3 DEVELOPMENT OF METEOROLOGICAL DATA BY PREPROCESSOR

The Preprocessor program prepares surface and upper air meteorological data for input to the Single Source (CRSTER) Model. As discussed in Sections 1.4 and 1.5, the program is applied to two meteorological data bases. The first of these is the set of hourly surface observations in card deck 144 format, while the second is the set of twice-daily mixing heights based on upper air observations. Both data bases are obtained from the National Climatic Center.

Because the 24-hour period for the Single Source (CRSTER) Model starts with the 1-hour period ending 0100 LST (Local Standard Time), whereas NWS data begin each day with the observation reported at 0000 LST, the Preprocessor skips the first hourly record of data in a year when reading NWS meteorological tapes. Sequential reading of the remaining data automatically makes this adjustment for each succeeding day. Meteorological data for the last hour in a year are assumed equal to that for the next to the last hour, with the exception of the mixing height, which is actually estimated for 2400 LST on the last day of the year.

2.3.1 Hourly Mixing Heights

Hourly values of the mixing height are determined by the Preprocessor from: 1) twice daily estimates of mixing height; 2) the local standard time of sunrise and sunset; and 3) hourly estimates of stability. The first are based on the method of Holzworth [9] and are available from the National Climatic Center (NCC), Asheville, NC. The second are computed by the Preprocessor from input data on the date, latitude, longitude, and time zone, using well known earth-sun relationships (e.g., see Sellers [10]. The third are discussed in Section 2.3.2. Two different interpolations are used by the Preprocessor; one is for application to rural sites while the other is for urban locations. Both sets of values are input to the Single Source (CRSTER) Model, which chooses between them depending upon the option specified by the user.

The method by which hourly mixing heights are determined is depicted schematically in Figure 2-3. The procedure uses values for the maximum mixing height (MAX) from the previous day (i-1), the computation day (i) and the following day (i+1) and for the minimum mixing height (MIN) for days (i) and (i+1). For urban sites between midnight and sunrise under neutral stability (i.e., Class D), the interpolation is between MAX_{i-1} at sunset and MAX_i at 1400 LST. Under stable conditions (i.e., Class E or F), the value for MIN_i is used. During the hours between sunrise and 1400 LST, if the stability was classified as neutral in the hour before sunrise, the earlier interpolation between MAX_{i-1} and MAX_i is continued; if the hour before sunrise was classified as stable, the interpolation is between MIN_i and MAX_i. For the period 1400 LST to sunset, the value for MAX_i is used. During the hours between sunset and midnight under neutral stability, the interpolation is between MAX_i at sunset and MAX_{i+1} at 1400 LST the next day; if the stability is stable, the interpolation is between MAX_i at sunset and MIN_{i+1} at midnight.

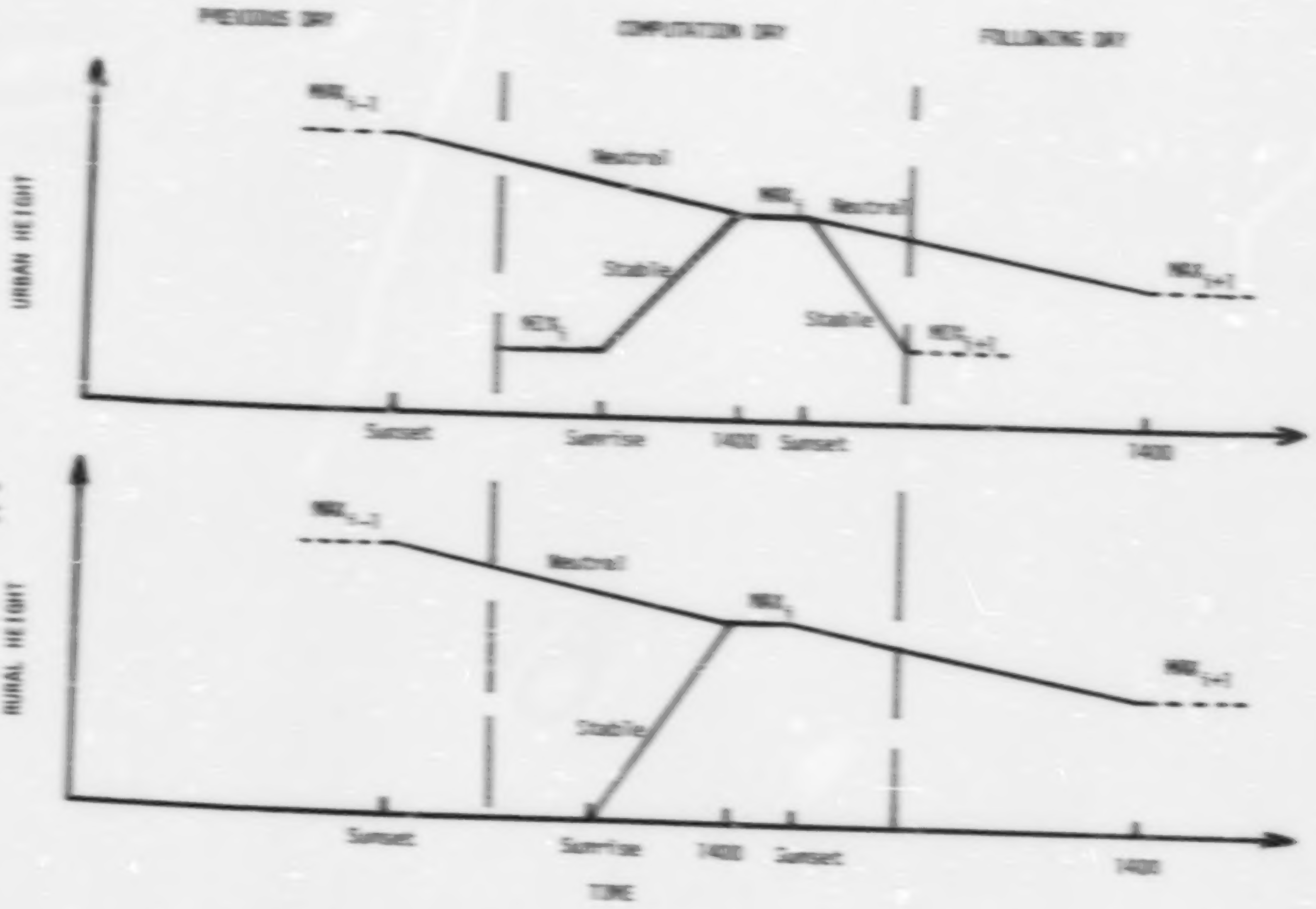


FIGURE 2-3

DETERMINATION OF HOURLY MIXING HEIGHTS BY THE SINGLE SOURCE (CRSTER) MODEL PREPROCESSOR

For rural sites between midnight and sunrise, the interpolation is between MAX_{i-1} at sunset and MAX_i at 1400 LST. During the hours between sunrise and 1400 LST, if stability was classified as neutral in the hour before sunrise, the earlier interpolation between MAX_{i-1} and MAX_i is continued; if the hour before sunrise was classified as stable, the interpolation is between 0 and MAX_i. For the period 1400 LST to sunset, the value for MAX_i is used. During sunset to midnight, the interpolation is between MAX_i at sunset and MAX_{i+1} at 1400 LST the next day.

2.3.2 Hourly Stability Classification

One of seven stability classes is determined from meteorological data for each hour by the Preprocessor. The first six of these categories (1-6) correspond to Pasquill's classifications (A-F). The seventh category corresponds to the 'dashes' in Pasquill's original classification [4] and represents the existence of a strong, ground-based nocturnal temperature inversion and non-definable wind flow conditions. The Single Source (CRSTER) Model restricts changes in stability to one class per hour, and in the urban mode, treats categories 5, 6 and 7 as category 4 for the purpose of estimating σ_y and σ_z. In the rural mode for hours classified as stability 7, the Single Source (CRSTER) Model does not compute concentrations (i.e., does not permit the plume to reach the ground).

Initially, the Preprocessor determines the hour angle of the sun and the times of sunrise and sunset from the day number, longitude, and time zone to permit differentiation of daytime and nighttime cases by the method of Woolf [18]. For daytime cases, the appropriate insolation class is selected by means of the Turner [6] objective method using cloud cover, ceiling height, and solar elevation as indicators. This method assigns net radiation indices, using the criteria shown in Table 2-4, for cases where the total cloud cover $\leq$ 5/10. If the cloud cover > 5/10, but less than 10/10 (overcast), the insolation class is reduced by one category when the ceiling height is between 7,000 and 16,000 ft. and by two categories for ceilings less than 7,000 ft. For a cloud cover of 10/10, the insolation class is reduced by one category when the ceiling height is greater than 16,000 ft. and by two categories for ceilings between 7,000 and

TABLE 2-4

INSOLATION CLASSES AS A FUNCTION OF SOLAR ALTITUDE FOR CLOUD COVER $\leq 5/10$*

Solar elevation angle (a)	Insolation class	Net Radiation Index
$0° < a \leq 15°$	Weak	1
$15° < a \leq 35°$	Slight	2
$35° < a \leq 60°$	Moderate	3
$60° < a$	Strong	4

*For $>5/10$ cloud cover, see Section 2.3.2

16,000 ft. For ceilings below 7,000 ft and 10/10 cloud cover (i.e., overcast), a net radiation of 0 is defined and neutral stability is specified. With the exception of the 10/10 low cloud cases, the net radiation index is never reduced below 1, or "weak". The final stability category is selected from Table 2-5 and Turner's insolation classes.

2.3.3 Wind Direction

Hourly data on wind direction input to the Preprocessor are tested for calms (coded as 0° by the NWS; note that a north wind is coded as 360°), and if present, the wind direction from the previous hour is substituted. If a calm occurs for the first observation of the year read by the Preprocessor, a default direction specified by the user is used instead.

The Preprocessor converts all wind directions to flow vectors by shifting input wind directions by 180°. This change is made because data reported by NWS indicate the direction from which the wind is blowing, whereas the Single Source (CRSTER) Model assumes input wind data specifying the direction towards which the wind is blowing. These flow vectors then are randomized by adding a random integer number of azimuth degrees between -4° and +5°. This procedure is applied to remove the directional bias introduced into the NWS data because they are reported to only the nearest 10°. The randomization gives the flow vector an equal probability of occurring anywhere within the 10° sector and so incorporates the natural fluctuations of this parameter.

2.3.4 Wind Speed

Hourly wind speed data are converted from the NWS reporting units of knots (kts) to the units of meters per second ($m\ s^{-1}$) used in the Single Source (CRSTER) Model. The multiplicative conversion factor is 0.51444. Wind speeds below 1.0 $m\ s^{-1}$ (calms included) are raised to 1.0 $m\ s^{-1}$ in the model.

TABLE 2-5

STABILITY CLASSIFICATION CRITERIA

Surface wind speed (knots)	Daytime Insolation				Overcast	Nighttime	
	Strong	Moderate	Slight	Weak		≥5/10 Cloud	<5/10 Cloud
≤ 1	1	1	2	3	4	6	7
2	1	2	2	3	4	6	7
3	1	2	2	3	4	6	7
4	1	2	3	4	4	5	6
5	1	2	3	4	4	5	6
6	2	2	3	4	4	5	6
7	2	2	3	4	4	4	5
8	2	3	3	4	4	4	5
9	2	3	3	4	4	4	5
10	3	3	4	4	4	4	5
11	3	3	4	4	4	4	4
≥ 12	3	4	4	4	4	4	4

2.3.5 Temperature

Hourly ambient temperature data are converted from the NWS reporting units of degrees Fahrenheit (°F) to the units of degrees Kelvin (°K) used in the Single Source (CRSTER) Model.

2.3.6 Missing Data

Meteorological data are input to the Preprocessor in two forms: (1) hourly NWS observations are read, from magnetic tape, one record per hour, and (2) daily minimum and maximum mixing heights are read from punched card input. Data may be missing from either of these sources for certain hours, days, or even months. The Preprocessor, however, performs checks for missing data records for only the magnetic tape of surface data. Because similar checks are not performed on the mixing height data, it is the user's responsibility to ensure that the information on these cards is complete and properly ordered.

Data checks on the meteorological data tape begin with the station identification number contained in each hourly record. If this number ever fails to match the station identification number specified by the user, an error message is printed and the program terminates. Next, the year, month, day and hour numbers contained in each data record are checked for consistency in their order and completeness. If one or more hourly records are found to be missing, or are out of order, then the program terminates after printing appropriate error messages. Because the data check procedures used in the Preprocessor can only sense missing data when the entire record is absent, if only one meteorological parameter is missing, e.g., wind speed, the Preprocessor will not flag such blank data entries and the blanks will be interpreted as zeros. It is recommended, therefore, that the user perform additional screening for missing data either manually or by other computer programs.

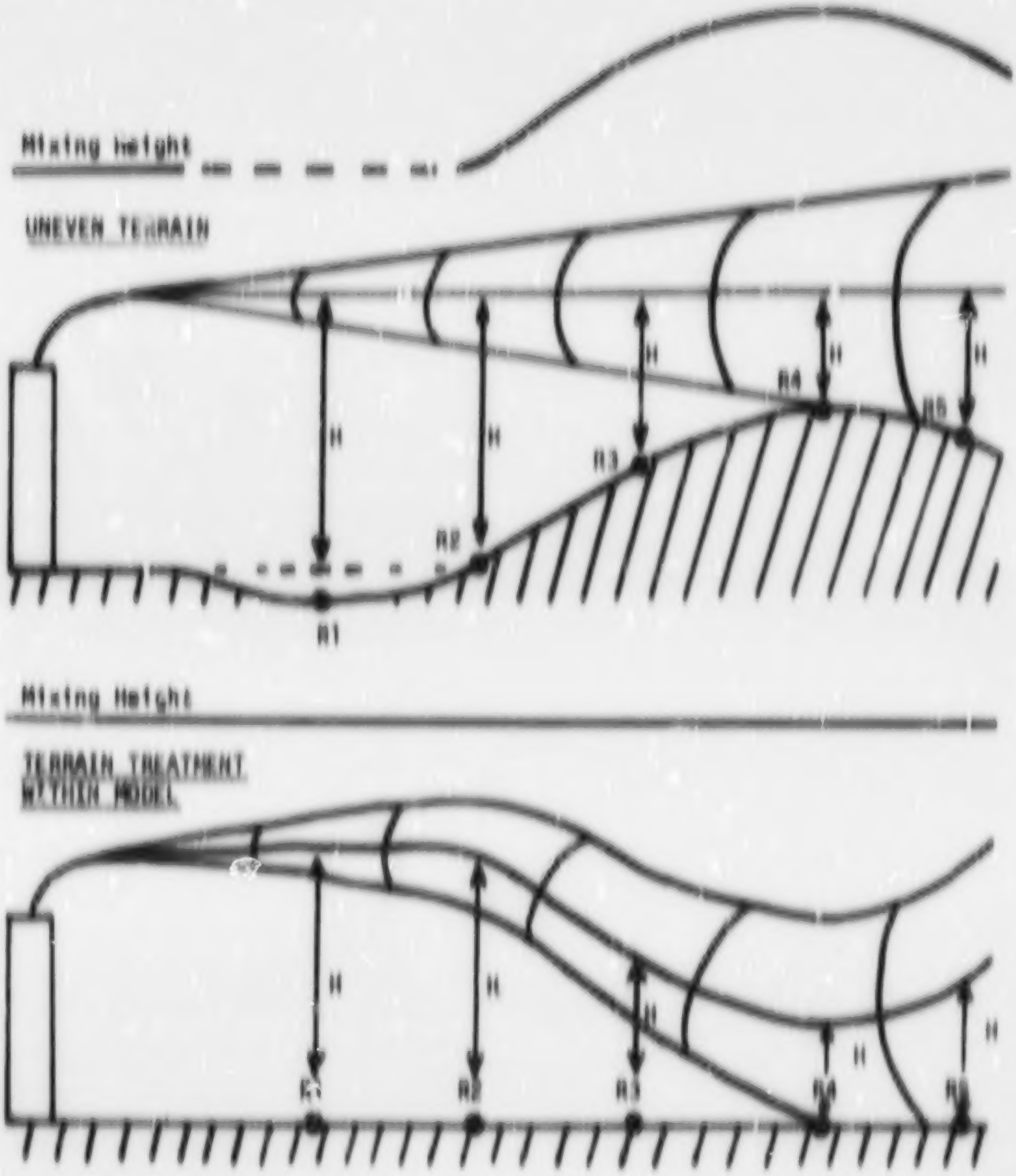
2.4 TERRAIN CONSIDERATIONS

The Single Source (CRSTER) Model is an uneven terrain model that takes into account certain changes in ground elevation between the point of source emissions (the plant) and the surrounding 180 receptor points. The method used in the Single Source (CRSTER) Model for making terrain adjustments is shown in Figure 2-4. This schematic shows that the height of the plume centerline (H) is lowered by an amount equal to the distance of the elevated receptor point above the ground elevation of the plant. The terrain adjustment made for any one receptor point does not affect concentrations at any other receptor point. When the height of a receptor is above the shortest plant stack height, then plume impaction on surrounding terrain is possible and the model terminates processing after printing an error message. Also, the model considers receptors below the ground elevation of the plant (e.g., receptor R1 in Figure 2-4) to be at the plant elevation.

Figure 2-4 also illustrates the mixing height assumption. This permits calculations to be made using Equations (2-11) through (2-13), i.e., without adding a vertical displacement term. This method of treating terrain adjustments assumes ground based receptors and is not equivalent to simply including a vertical coordinate term z in the Gaussian plume equation (e.g., Equation (3.1) in Turner [7]). That method would not imply any changes in terrain elevation at all. Rather, the value of z would specify the height at which the receptor point would be "floating" in the air, and reflections of the plume at the ground close to the stack, caused by elevated terrain, would not be simulated.

2.5 RECEPTOR ARRAY

The Single Source (CRSTER) Model predicts concentrations for each hour at a circular field of 180 receptors, as shown in Figure 2-2. The receptor array is defined by: (1) five downwind ring distances and (2) 36 radials (one for every 10° of azimuth). Although the 36 azimuths are fixed, selection of the five ring distances is made by the user and warrants judicious consideration since the choice of locations for receptor sites can result in major


Mixing height
UNEVEN TERRAIN
H
H
H
H
H
R1
R2
R3
R4
R5
Mixing Height
TERRAIN TREATMENT WITHIN MODEL
H
H
H
H
H
R1
R2
R3
R4
R5

Note: R1-R5 are receptor points at 5 ring distances.

FIGURE 2-4

ILLUSTRATION OF THE METHOD FOR TERRAIN ADJUSTMENT IN THE SINGLE SOURCE (CRSTER) MODEL differences in the evaluation of impact on air quality. Once the ring distances have been chosen, terrain elevations can be obtained from a topographic USGS quadrangle map of the area (scale 1:24,000 is suggested) available from the U.S. Geological Survey, Washington, D.C. 20242.

Any one of a number of procedures can be used for preliminary determination of receptor ring distances in a Single Source (CRSTER) Model analysis. The UNAMAP programs and the PTMAX* program in particular have been developed to calculate the distance to the maximum 1-hour concentration from a single point source for each of 49 stability/wind speed combinations. The model equations used in PTMAX are the same as those in the Single Source (CRSTER) Model except that PTMAX does not account for elevated terrain or for limited mixing. The use of PTMAX does provide first order approximations to the selection of receptor distances which can be refined through successive applications of the Single Source (CRSTER) Model.

2.6 CONSIDERATION OF SOURCE CHARACTERISTICS

The emission source parameters which are input to the Single Source (CRSTER) Model are:

- Plant elevation
- Stack parameters, for each stack
  - pollutant emission rate (Q)
  - stack gas velocity (v_s)
  - stack gas temperature (T_s)
  - stack exit diameter (d)
  - physical stack height (h_s)

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*PTMAX is available through EPA's User's Network for Applied Models of Air Pollution (UNAMAP) and has been documented by Khanna [11].

The plant elevation is used in the analysis of uneven terrain by the model (see Section 2.5). Effectively, the plant elevation is taken as the reference plane and all receptor elevations, plume height and mixing heights are calculated relative to this plane.

The stack parameters are used by two components of the Single Source (CRSTER) Model. The emission rate Q for a stack is used directly in the modified Gaussian plume equations (2-11) and (2-12). The stack gas parameter v_s, T_s, and d are used in Briggs' plume rise equations (2-5) through (2-10) to calculate the bouyancy flux parameter F. The estimate of plume rise Δh is then added to the physical stack height h_s to obtain the effective stack height H used in the modified Gaussian plume equation (2-11).

The Single Source (CRSTER) Model provides for input of different values for Q for each month. Since variations in emissions are often due to changes in a plant's operating conditions, which in turn affects the values for v_s and T_s, the model allows monthly values to be input for these stack parameters as well. For each 1-hour concentration computed by the Single Source (CRSTER) Model, the values of Q, v_s and T_s used are those corresponding to the month of the year which contains the 1-hour period. Thus, an execution of the model for an entire year will match up the monthly stack parameters with the appropriate month of meteorological data to provide a realistic simulation of actual conditions.

The Single Source (CRSTER) Model assumes one geographical source location but provides for specifying up to 19 individual stacks at the one plant site. For the case of multiple stacks, each stack is considered separately and calculations made based on its individual stack parameters. The program totals the impacts of each individual stack at each of the 180 receptor points.

Thus, concentrations output for each receptor point represent the impacts from all stacks. In order to obtain the individual contributions from each stack to concentrations at a receptor point, it is necessary to run the Single Source (CRSTER) Model in source-contribution mode, as discussed below.

2.7 SOURCE-CONTRIBUTION MODE

When the source-contribution mode is specified for the Single Source (CRSTER) Model, the concentrations output for each averaging time are reported to show each stack's contribution to each receptor point. The model generates a source-contribution table for each day processed. The receptor points for which source-contributions are desired must be specifically identified in the model input parameters by a paired number giving the ring distance and the azimuth coordinates of the receptor. The number of such receptors is limited to 20, though a different set of 20 may be specified for each averaging period. Due to this restriction, the source-contribution mode is normally requested in a model execution subsequent to review of the output from a multi-stack model execution. The model will output source contributions for only those receptors and averaging periods so identified. Thus, the user has complete control over the output produced in this mode. A detailed discussion of the source-contribution output and its interpretation is given in Section 4.3.4.a.

2.8 AVERAGING PROCESS AND RANKING PROCEDURE

The basic time increment for the Single Source (CRSTER) Model is one hour, and 1-hour concentrations are computed for each of the 8,760 hours in a given year (8,784 hours in a leap year). The 1-hour values are averaged to obtain concentrations for longer averaging periods. The Single Source (CRSTER) Model reports pollutant concentrations for 1-hour, 3-hour, 24-hour, and annual averaging periods. In addition, calculations can be selected for a variable averaging period from any one of the following: 2, 4, 6, 8, or 12 hours. Concentrations for each averaging time are computed for discrete, non-overlapping time periods, i.e., running averages are not computed. Thus, the model can report for each day:

- Twenty-four 1-hour average concentrations corresponding to the periods 0000-0100 LST, 0100-0200 LST, ..., 2300-2400 LST.
- Eight 3-hour average concentrations corresponding to the periods 0000-0300 LST, 0300-0600 LST, ..., 2100-2400 LST.
- One 24-hour average concentration corresponding to the period 0000-2400 LST.

Similar fixed time periods are used for the variable averaging period.

Concentration maxima are output by the Single Source (CRSTER) Model in several different forms, as shown in Appendix B. An optional output is a magnetic tape containing all of the 1-hour, 24-hour and annual average concentrations calculated by the model. This data tape can serve as a convenient input to other analysis programs (see Section 3.2.2). The printed output consists of the following:

- A table of the highest concentration at each of the 180 receptors, for each averaging period. For a given averaging time, this table is obtained by ranking, at each receptor point, the concentrations estimated for the entire year and then selecting the highest value from each of the 180 rankings. Examples are the tables on pages B-15, B-16, B-18, B-20 and B-22 (in Appendix B).
- The maximum highest concentration at any receptor, for each averaging period. For a given averaging time, this maximum is obtained by selecting the maximum of the 180 entries in the above table of highest concentrations. Examples are the concentrations listed on the second line of the above mentioned tables in Appendix B.
- A table of the second-highest concentration at each of the 180 receptors, for each averaging period except the annual. For a given averaging time, this table is obtained by discarding the highest value at each of the 180 receptors and selecting the second-highest value from each of the 180 rankings. Examples are the tables on pages B-17, B-19, B-21 and B-23.
- The maximum second-highest concentration at any receptor, for each averaging period except the annual. For a given averaging time, this maximum is obtained by selecting the maximum of the 180 entries in the above table of second-highest concentrations. Examples are the concentrations listed on the second line of the above mentioned tables in Appendix B.
- A ranking of the 50 highest concentrations for the entire year, for each averaging period except the annual. Examples are the tables on pages B-24 through B-27.

Second-highest concentrations are output since the National Ambient Air Quality Standards (NAAQS) for short-term averaging times are not to be exceeded more than once per year. The maximum second-highest concentration at any receptor is especially relevant since EPA's Guidelines [12] specify that this value should be used to determine compliance of a plant with NAAQS on all time scales shorter than the annual average.

It should be noted that the maximum second-highest concentration at any receptor for a given averaging time would not be necessarily second in the ranking of the 50 highest concentrations for the entire year. More likely it would be farther down the ranking of the 50 highest. This factor serves to distinguish the difference in the procedure by which these values are computed. The maximum of the second-highest concentrations is obtained by discarding the highest concentration at each receptor site and selecting the highest value among those remaining. The 50 highest concentrations for an entire year are obtained by combining all concentrations (regardless of receptor) in one ranking. Thus, the second concentration in the ranking of 50 is also most likely a highest concentration at one of the 180 receptors (but not the maximum highest concentration).

2.9 LIMITATIONS

This section discusses the limitations associated with the assumptions inherent in the Single Source (CRSTER) Model.

2.9.1 Steady-State Assumptions

The Gaussian plume equation is representative of steady-state conditions and a homogeneous atmosphere. Its use is less valid when emissions, wind speeds, directions, local turbulence and atmospheric stability are changing rapidly with time or distance. This steady-state condition translates into the following source and meteorological factors which must be considered:

- Continuous uniform emission rate
- Homogeneous horizontal wind field
- Representative hourly mean wind speed and direction
- No directional wind shear in the vertical
- Constant eddy diffusivities
- No plume history
- No material depletion or atmospheric transformation

Most pollutant sources exhibit significant diurnal variations in their emission rates. Thus, a monthly mean emission rate as used by the model may not be representative for computing short-term concentrations.

The assumption of a homogeneous horizontal wind field is an idealized situation. Uneven terrain generally complicates the transport and diffusion of a plume by altering the speed and direction of the air flow. This assumption also is unrealistic for time periods when large shifts in either direction or speed occur, as might be associated with the passage of a weather front or the onset of a local lake or sea breeze circulation. Furthermore, at sufficiently large downwind distances, synoptic scale motions, will cause the mean wind direction to vary. Since the model is very sensitive to changes in wind direction, results may be in error for time periods or over distances during which these conditions occur.

Wind direction is generally found to veer (turn clockwise) and increase in speed with increasing height (in the northern hemisphere at extratropical latitudes) due to the effects of friction at the earth's surface. The amount of veering in direction that occurs varies and is related to the roughness of the surface, the thermal wind component (horizontal temperature gradient) and the stability of the atmosphere (vertical temperature gradient). Over smooth terrain, such as the great plains, the degree of veering from this wind shear effect is on the order of 10°. Over average terrain with small changes in elevation and with some trees and shrubs, the amount of veering with height is about 15° to 20°. Over rough terrain, quite hilly or mountaneous or with numerous buildings and tall vegetation, the amount of veering with height can be as much as 40° to 50°. The thermal wind component may act in either a clockwise or counter-clockwise direction and may be sufficient in some cases to cause backing (turn counter-clockwise) of the wind direction with height. The Single Source (CRSTER) Model assumes no directional wind shear in the vertical. Thus, errors in pollutant concentrations estimated by the model, due to using a nonrepresentative wind direction, will increase with increasing surface (terrain) roughness.

The values of the dispersion coefficients σ_y and σ_z in the Gaussian plume equation are assumed to vary only in the downwind direction, i.e., they are assumed invariant with height and crosswind distance. This condition is not necessarily satisfied in the atmosphere, particularly in the vertical direction, thus necessitating the use of spatially representative parameters. The Pasquill-Gifford estimates of dispersion coefficients are based on measurements taken in open, level to gently rolling country and so may not be representative of coastal areas or those with significant terrain features. Also, since the field measurements were taken in the surface boundary layer of the atmosphere, the derived dispersion coefficients may be less representative at the heights of tall stacks (i.e., above 100 m). The dispersion coefficients are valid only for downwind distances greater than 100 m from the plant. Beyond a few km downwind, the estimates are based on limited data and so may be less accurate. Use of the Pasquill-Gifford dispersion coefficients for a finite number of stability "states" or categories represents an approximation to the continuous changes which occur in the atmosphere.

The assumption of no plume history in the Single Source (CRSTER) Model eliminates consideration of the cumulative effects from consecutive 1-hour periods and does not allow for changes in the wind with time to affect the path taken by the plume downwind. The average ambient concentration at a receptor site may be significantly influenced by emissions released from the plant during previous periods.

The assumption of no atmospheric transformations or depletion of the plume constituents limits the validity of the Single Source (CRSTER) Model to certain pollutants and conditions. Of the five directly-emitted criteria pollutants, nitrogen dioxide and non-methane hydrocarbons participate in the most rapid and complex chemical reactions in the atmosphere, and thus cannot be simulated with this model. The conversion of sulfur oxides in the atmosphere is highly variable, with oxidation rates in the range of 0.5% to 10% per hour [13]. Thus, estimations of ambient SO_2 concentrations can be simulated with the Single Source (CRSTER) Model as long as the travel time to a downwind receptor (equal to the distance x divided by the wind speed u) is short relative to the half-life of SO_2 in a particular situation.

Suspended particulate matter can also be simulated with the Single Source (CRSTER) Model when the size distributions do not include a significant number of particles above 20 μm in diameter. Above this limit, a particle generally has an appreciable settling velocity and so the use of the model would introduce errors into the predicted concentrations.

Since carbon monoxide is gaseous and inert, it satisfies the modeling assumption but generally is not associated with point emission sources.

2.9.2 Terrain Adjustment

Elevated terrain can significantly affect the downwind trajectory of a plume by disturbing the wind flow field. Also, large scale eddies can form in the lee of a hill or ridge resulting in increased turbulence and diffusion. The Single Source (CRSTER) Model does not adjust plume flow vectors and dispersion for such terrain effects; the only terrain adjustment made in the model is to lower the plume centerline to account for a receptor location above that of the base elevation of the plant (see Section 2.4). Thus, the reliability of the Single Source (CRSTER) Model is more limited for receptor points which lie in significantly uneven terrain.

2.9.3 Mixing Height

The Single Source (CRSTER) Model assumes negligible concentration whenever the effective stack height H exceeds the mixing height L at a given receptor location. When this condition occurs, the plume is assumed to enter and remain in the elevated stable layer and no contribution from the plume at that receptor is computed. When these conditions occur and $H > L$, the Single Source (CRSTER) Model may underestimate pollutant concentrations by assuming no source contribution.

2.9.4 Calm Winds

Pollutant concentrations estimated by the Gaussian plume equation used in the Single Source (CRSTER) Model are inversely proportional to average wind speed (see Table 2-3). This relationship implies that concentrations will become infinite as the wind speed approaches zero, which is clearly not the case. Low or calm wind speeds violate the assumption made in solving the differential equation of diffusion that dilution dominates diffusion in the downwind direction. For this reason, the model cannot simulate the no-wind case of isotropic diffusion from a point source or diffusion under low wind conditions, i.e., $u < 1.0$ ms^{-1}. Thus, hourly mean wind speeds below this value are increased to 1.0 ms^{-1} to preclude an invalid application of the model.

When wind speeds are less than 1.0 ms^{-1}, but greater than calm, the measured wind direction is used. However, when calm conditions occur there is no measured wind direction. In that case, the model uses the wind direction from the previous (non-calm) hour in the dispersion calculations. Problems can arise if a series of consecutive calm hours occur, because then the model will assume a single, persistent wind direction for the duration of the calms. Such an assumption of directional persistence may cause the model to overestimate pollutant concentrations.

2.9.5 Other Limitations

The diffusion of pollutant emissions from an elevated point source is often less than ideal due to aerodynamic effects. These effects can result from the interaction of the wind with the physical structure of the plant, upwind terrain, or from a low stack gas exit velocity. Such interaction can retard, or in the extreme case, prevent plume rise. The extreme case is commonly referred to as plume "downwash". With downwash, the effluent is brought downward toward the ground into the wake of the plant, from which point it diffuses as though emitted very close to the ground. Retardation of plume rise and downwash can significantly increase the resulting impact of a source. The Single Source (CRSTER) Model does not consider these aerodynamic complications. Small sources, in particular, are likely to have low stack heights and low gas exit velocities. Therefore, these sources, as a class, are more likely to be influenced by aerodynamic effects.

In addition, model estimations for low-level sources may be inaccurate under meteorological conditions that include low mixing heights. When the estimated mixing height for a given hour is near the elevation of a low level source, the emissions may be released either below or above the mixing height. The first condition will result in a high concentration impact, while the second will have no impact on ground-level concentrations. Due to the fact the hourly mixing height is just an estimate, the model may simulate the wrong condition and so make either a large over or underestimation of the impact of a low level source. The user is therefore advised to review the meteorological and source emissions data printouts to identify the occurrence of such conditions, and where found, to flag the estimated concentrations as possibly being inaccurate.

When a plant configuration has multiple stacks, the separation between stacks can act as an initial plume spread in the crosswind direction, reducing downwind concentrations. This effect is at a maximum for wind directions normal to a line of stacks, and is nearly zero when the wind is parallel to a line of stacks. The Single Source (CRSTER) Model does not account for the effects of stack separation since all stacks are assumed to be at the same geographical location. Thus, the model may somewhat overestimate concentrations from multi-stack plants whenever stack separation is significant relative to the crosswind dispersion coefficient σ_y.

The Briggs plume rise formulas used in the Single Source (CRSTER) Model (see Section 2.2.5) are for hot, buoyant plumes. Some small industrial sources do not emit plumes with temperatures significantly in excess of those of ambient air. Therefore, a simulation of these sources with the Single Source (CRSTER) Model may tend to overestimate receptor concentrations since plume rise will be underestimated. Briggs [1] has developed equations which can be used to calculate plume rise for non-buoyant plumes, however, they are not included in the Single Source (CRSTER) Model.

3. DATA REQUIREMENTS AND OUTPUT

This chapter discusses the input data requirements for the Preprocessor and Single Source (CRSTER) Model programs, and the output they produce. Input is described by the type of information required, its source, limitations, restrictions, options and form. Program output is described by the information provided, its form and ultimate usage. Specific information on input and output format for these programs is given in Section 4.

3.1 PREPROCESSOR PROGRAM

The Preprocessor program is designed to directly utilize meteorological information available from the National Climatic Center (NCC). Data obtained from other sites can be utilized if the information satisfies the input requirements described below and the formats given in Section 4.

3.1.1 Input Data Requirements

a. Surface Station Number. This number identifies the National Weather Service (NWS) surface observation station for which hourly meteorological data is input to the Preprocessor. This number is the WBAN station identification number, not the WMO block identification number which is typically used by the NWS. The Survey of TD-1440 [14] tabulates WBAN station numbers for all surface stations for which hourly meteorological data are available from NCC. The surface station selected for analysis of the plant should be representative of the site. The station number is a five-digit integer, input in card form.

b. Year of Surface Data. This input parameter identifies the year during which the meteorological data was observed, hereafter referred to as the "year of record". Only the last two digits of the year are used,with the input in card form.

c. Latitude of Surface Station. This input parameter gives the geographic latitude coordinate for the surface station in degrees (north of the equator). The directory of NWS Offices and Stations [15] lists the latitude for each station. The input is in card form.

d. Longitude of Surface Station. This input gives the geographic longitude coordinate for the surface station in degrees (west of Greenwich). The directory of NWS Offices and Stations [15] lists the longitude for each station. The input is in card form.

e. Time Zone. This input parameter is a code for the time zone in which the surface station is located. The standard time zone for a given station can be determined from the nationwide map given in any telephone directory. The standard values for this parameter are: 05 = Eastern, 06 = Central, 07 = Mountain, 08 = Pacific. The value corresponds to the number of time zones west of Greenwich Mean Time. The input is in card form.

f. Number of Days in the Year. This input variable gives the number of days in the year of record. The value input must be 365,or 366 for a leap year. The input is in card form.

g. Random Number Seed. This input variable is an integer, chosen randomly, with a value between 1,000 and 9,999,999,999. This initiates the wind direction randomization. In the program this variable is multiplied by 10,000 prior to entry into the random number generator. The input is in card form.

h. Hourly Surface Observations. These data are the "Hourly Surface Observations in Card Deck 144 Format" available from NCC for the year of record. The Preprocessor performs checks for missing data from this file but can only sense when an entire record (one hour of data) is missing. Thus, if data for only one parameter are absent, the Preprocessor will not flag such gaps in the input data. It is recommended, therefore, that the user perform independent integrity and completeness checks. The input of this data is in magnetic tape form.

7. Mixing Height Data. These data input the nocturnal (minimum) and afternoon (maximum) mixing height for each day in the year of record. The information required for each day includes:

- Upper Air Station Number - this number is the WBAN station identification number identifying the NWS upper air observation station used to calculate mixing heights. The List of Upper Air Stations [14] tabulates such WBAN numbers. The station must be representative of the plant site.
- Year - the last two digits of the year of record for the mixing height data.
- Month - the month number corresponding to a given set of mixing heights.
- Day - the calendar day number corresponding to a given set of mixing heights.
- Nocturnal Mixing Height - the minimum mixing height for a given day calculated from the 1200 GMT upper air sounding on that day.
- Afternoon Mixing Height - the maximum mixing height for a given day calculated from the 1200 GMT upper air sounding on that day.

The input of mixing height data is in card form where one card is required for each day of the year of record. The first card of this file must contain mixing height data for December 31 of the preceding year, while the last card of the file must contain data for January 1 of the year succeeding the year of record. The twice daily mixing height cards must be punched from information available from NCC, on either magnetic tape or in printed tabular form, for an appropriate NWS upper air observation station in the year of record (see Section 4.2.3).

3.1.2 Output Information

Two types of output are generated by the Preprocessor program: (1) a magnetic tape of hourly meteorological data for the year of record, and (2) printed output of program diagnostic messages. The output tape serves as direct input to the Single Source (CRSTER) Model program as the hourly values of wind speed, flow vector, randomized flow vector, stability and temperature are structured in the format required by the model. The printed output informs the user of any inconsistencies or missing records in the output tape as a result of deficiencies in the hourly surface observation data input to the Preprocessor. A description of the error message directory for the Preprocessor program and recommended user action are given in Section 4.2.4.

3.2 SINGLE SOURCE (CRSTER) MODEL

3.2.1 Input Data Requirements

a. Heading Data. This information is input to label the model output and generally contains the plant name and the air pollutant being modeled. The input is in card form.

b. Comments (Optional). Comments are input in card form and are printed at the beginning of the model output. Any number of comment cards may be input to the model, but the last card must be totally blank (a delimiter) and is required regardless of whether any comment cards are input.

c. Namelist Data. A variety of namelist data required by the model are input in card form. Since namelist input is a free format, there is no fixed number of cards. These data are itemized below:

Parameter Name	
IUR	Urban/Rural Indicator - this parameter specifies whether the urban or rural option is selected for analysis of the plant site. The information is used by the model to select one of the two sets of mixing heights on the preprocessed hourly meteorological data tape. Values for this variable are restricted to "1" (rural) and "2" (urban).
ITAP	Output Tape Indicator (Optional) - this parameter specifies whether a tape of calculated concentrations is to be output. Values are restricted to "0" (no) and "1" (yes) with 0 as the default value.
IPTZ	Elevation Indicator (Optional) - this parameter specifies whether the plant and receptors are located in flat or uneven terrain. Values are restricted to "0" for the flat terrain case (plant and terrain elevations set to 0) and to "1" for the uneven terrain case (plant and terrain elevations and delimiter card must not be input with 0 as the default value).
DAY	Day Indicators (Optional) - these parameters consist of an array of 366 numbers corresponding to the calendar day in the year of record. Concentrations are not calculated for each day assigned a value of "0" and are calculated for each day assigned a value of "1". The default value is "1" for all 366 positions, but for non-leap years, the 366th position must be set to "0".
RNG	Receptor Ring Distances - these input data consist of five receptor ring distances selected for analysis.

Parameter Name	
IMET	Meteorological Output Indicator (Optional) - this parameter specifies whether the hourly meteorological data for each day used in the model calculations will be printed. Values are restricted to "0" (no output) and to "1" (output) with a default value of "1".
ISS	Surface Station Number - this number identifies the NWS surface station observations input to the model. This number must be the same as the "Surface Station Number" input to the Preprocessor.
ISY	Surface Station Year - this parameter identifies the year of record for the surface meteorological data input to the model. This year must be the same as the "Year of Surface Data" input to the Preprocessor.
IVS	Upper Air Station Number - this number identifies the NWS upper air station observations used in computing mixing heights input to the model. This number must be the same as the "Upper Air Station Number" input to the Preprocessor.
IUY	Upper Air Station Year - this parameter identifies the year of record for the mixing height data input to the model. This year must be the same as the "Year" input to the Preprocessor.
IVT	Variable Averaging Time (Optional) - this parameter specifies the length of the concentration averaging period used in the model calculations. The values, in hours, are restricted to "0" (no variable period), or one of the following: "2", "4", "6", "8", and "12". The default value is "0".
IQCK	Monthly Emissions Indicator (Optional) - this parameter specifies whether separate monthly emission rates will be input for each stack. Values are restricted to "0" (no) and "1" (yes, monthly emissions for each stack must be input). The default value is "0".*
QSSN	Monthly Emission Rates (Optional) - These data consist of the twelve monthly emission rates for each stack at the plant and must be input when this option is selected.
IVCK	Monthly Stack Gas Exit Velocity Indicator (Optional) - this parameter specifies whether separate monthly stack gas exit velocities will be input for each stack. The values are restricted to "0" (no) and "1" (yes, monthly stack gas exit velocities for each stack must be input). The default value is "0".*
VSSN	Monthly Stack Gas Exit Velocities (Optional) - these data consist of the twelve monthly stack gas exit velocities each stack and must be input when this option is selected.
ITCK	Monthly Stack Gas Temperature Indicator (Optional) - this parameter specifies whether separate monthly stack gas temperatures will be input for each stack. Values are restricted to "0" (no) and "1" (yes, monthly stack gas temperatures for each stack must be input). The default value is "0".*

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*Under default conditions, the annual value for this parameter, input with the stack data, is used.

Parameter Name	
TSSN	Monthly Stack Gas Temperatures (Optional) - these data consist of the twelve monthly stack gas temperatures for each stack at the plant and must be input if this option is selected.
ISC	Source Contributions Indicator (Optional) - this parameter specifies whether separate source contribution tables will be generated in the model output for selected receptors. Values are restricted to "0" (no) and "1" (yes, source contribution receptors for each selected averaging period must be input). The default value is "0".
SC1	1-Hour Source Contribution Receptors (Optional) - these data consist of the distance and azimuth coordinates of each receptor for which 1-hour source contributions will be printed. The receptor coordinates are restricted to the standard model 180-receptor array. No more than 20 receptors can be selected for source contribution output. (Distances are in kilometers and azimuth range from 1 to 36).
SC3	3-Hour Source Contribution Receptors (Optional) - these data consist of the distance and azimuth coordinates of each receptor for which 3-hour source contributions will be printed. The receptor coordinates are restricted to the standard model 180-receptor array. No more than 20 receptors can be selected for source contribution output.(Distances are in kilometers and azimuths range from 1 to 36).
SCN	Variables Averaging Period Source Contribution Receptors (Optional) - these data consist of the distance and azimuth coordinates for each receptor for which source contributions for the variable averaging period will be printed. The receptor coordinates are restricted to the standard model 180-receptor array. No more than 20 receptors can be selected for source contribution output.(Distances are in kilometers and azimuths range from 1 to 36).
SC24	24-Hour Source Contribution Receptors (Optional) - these data consist of the distance and azimuth coordinates of each receptor for which 24-hour source contributions will be printed. The receptor coordinates are restricted to the standard model 180-receptor array. No more than 20 receptors can be selected for source contribution output.(Distances are in kilometers and azimuths range from 1 to 36).
SCAN	Annual Source Contribution Receptors (Optional) - these data consist of the distance and azimuth coordinates of each receptor for which annual source contributions will be printed. The receptor coordinates are restricted to the standard model 180-receptor array. No more than 20 receptors can be selected for source contribution output. (Distances are in kilometers and azimuths range from 1 to 36).

d. Plant Elevation (Optional). This parameter inputs the elevation of the plant site being modeled in feet above mean sea level (MSL). This parameters is required if namelist variable IPTZ=1.

e. Receptor Elevations (Optional). These data are requred input if the "uneven terrain" option (ITPZ=1) is selected and consist of the receptor elevations (in feet above MSL). The default values are 0. A blank delimiter card is required to terminate this input file.

f. Stack Data. These data consist of individual stack information for a maximum of 10 stacks. The data for each stack is presented on two cards with the first card in each providing a stack identification, and the second card providing data on the following stack parameters:

- Emission Rate - this variable specifies the average pollutant emission rate for a given stack to be used in the model calculations for the year of record. If "Monthly Emission Rates" are input, this variable can be left unspecified.
- Stack Height - this variable specifies the physical height of a given stack above the plant elevation.
- Stack Diameter - this variable specifies the diameter of the opening at the top of the stack.
- Stack Gas Exit Velocity - this variable specifies the average stack gas exit velocity for a given stack to be used in the model calculations for the year of record. If "Monthly Stack Gas Exit Velocities" are input, this variable can be left unspecified.
- Stack Gas Temperature - this variable specifies the average stack gas temperature for a given stack to be used in the model calculations for the year of record. If "Monthly Stack Gas Temperatures" are input, this variable can be left unspecified.

Two blank delimiter cards are required to terminate this input file.

g. Preprocessed Hourly Meteorological Data. These data are a magnetic tape file of hourly values of wind speed, flow vector, randomized flow vector, stability class, mixing height and ambient temperature output by the Preprocessor.

3.2.2 Output Information

The output generated by the Single Source (CRSTER) Model program is in two forms: (1) printed input data and calculated concentration values, and (2) a magnetic tape (optional) containing 1-hour, 24-hour and annual average concentrations. The printed output includes tables for each averaging period of the highest and second-highest concentrations at each receptor point, and tables of the 50 highest concentrations for the entire year for each averaging period (except the annual). The contents of these tables and how they are produced is detailed in Section 2.6. If specified, source contribution tables for each averaging period will be output, in which case, the printing of all other concentration tables will be suppressed. These outputs are illustrated and described in detail in Section 4.3.6.

Each of these model outputs have potential application in the analysis of air quality impact. The maximum annual concentration and the maximum second-highest concentration for short term averaging periods are especially relevant in determining compliance of a plant with National Ambient Air Quality Standards (NAAQS), and if necessary, to determine required source reductions to achieve NAAQS. The tables of highest and second-highest concentrations for each averaging period can be used to plot concentration isopleths on maps of the area surrounding a plant, providing information on the spatial variation of maximum concentration levels. These concentration isopleths can also be overlaid on population density maps to obtain measures of total population exposure to different pollutants and levels. The ranking of the 50 highest concentrations for each averaging period can be used to determine the number of times in a year that ambient concentrations exceed a particular level (e.g., one of the NAAQS) in the vicinity of a plant. The concentration data written on the output tape provide a complete record of model predictions for each receptor point and so can be used as input to various analysis programs. For example, the concentrations at a given receptor can be rank ordered by size and their frequency distribution characterized using standard techniques [16]. Such frequency distributions can be used for comparison with distributions of measured data for the same receptor site in model validation studies (see

Appendix F). The concentration data can also be ordered in time for a given receptor to provide a time series of model predictions for comparisons with measured data or statistical trend analysis. Finally, the source contribution tables allow the impact of individual stacks to be determined. Such information is required when it is necessary to examine alternative control strategies for reducing plant emissions toward achieving compliance with NAAQS. Individual stack contributions are also required in evaluations of proposed new facilities with regard to Prevention of Significant Deterioration regulations.

4. SINGLE SOURCE (CRSTER) MODEL USER'S GUIDE

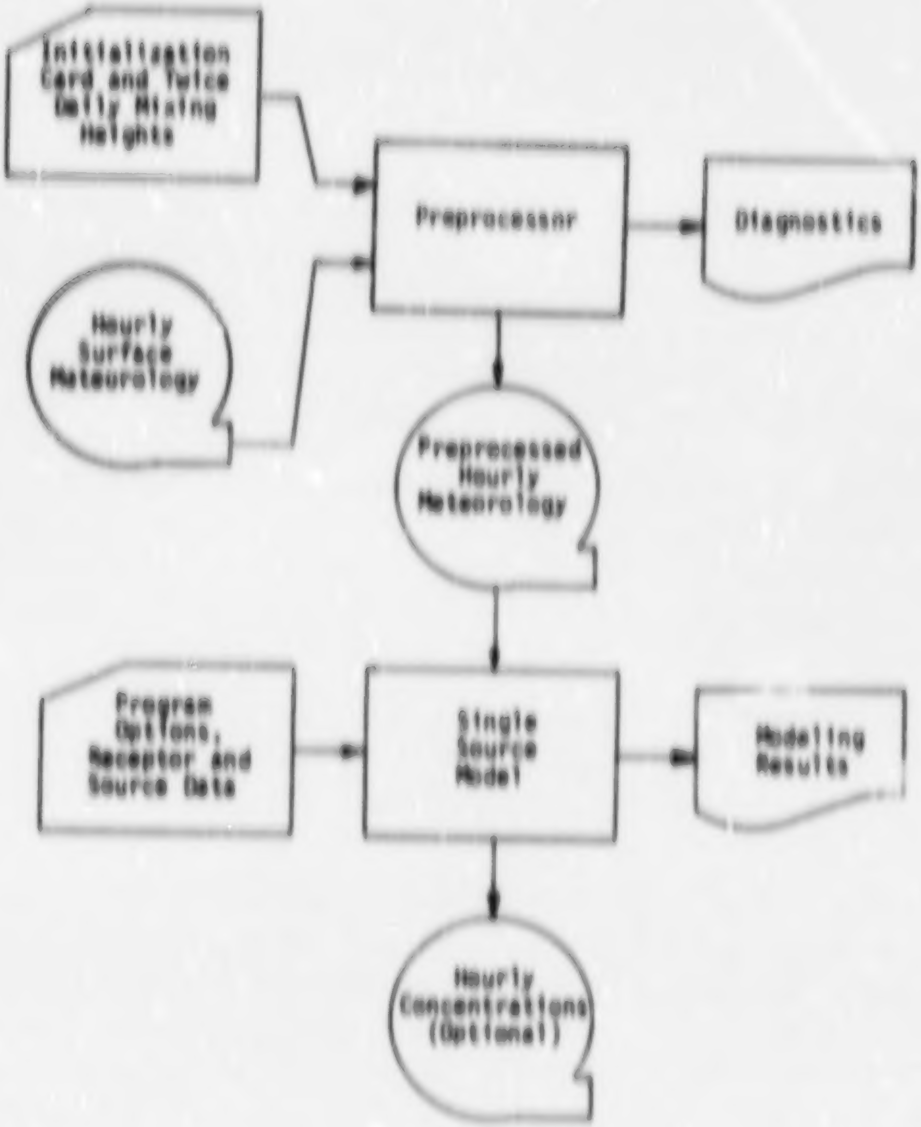
4.1 INTRODUCTION

The procedure for modeling using the Single Source (CRSTER) Model involves two data processing steps. First, a Preprocessor program prepares the meteorological data in the hourly format required for input to the Model. Second, these data and appropriate source emissions and stack data for the plant are input to the Single Source (CRSTER) Model and predicted concentrations obtained. Figure 4-1 is a flow diagram depicting the modeling procedure.

The Preprocessor program generates a magnetic tape of hourly meteorological data for the Single Source Model. The input required by the Preprocessor are hourly meteorological surface observations and twice daily mixing heights. In the process of generating data for the Single Source (CRSTER) Model, the Preprocessor also performs several quality assurance data checks.

The tape of hourly meteorology, output by the Preprocessor program, can be used with the Single Source (CRSTER) Model to model any plant for which the selected combination of upper air station and surface station data is applicable. Thus, output should be stored permanently whenever possible for future applications.

The Single Source (CRSTER) Model calculates concentrations for an entire year from a plant with up to 19 individual stacks and prints out the highest 1-hour, 3-hour, 24-hour, as well as annual average, concentrations at a set of 180 receptors, surrounding the plant. In addition, concentrations can be obtained for a variable averaging period which can be selected as 2, 4, 6, 8 or 12 hours. The model can optionally produce output for individual source contributions at selected receptor points for each time interval in a day. It can also generate a magnetic tape file of hourly, daily and annual concentrations at each receptor point.



Initialization Card and Twice Daily Mixing Heights
Preprocessor
Diagnostics
Hourly Surface Meteorology
Preprocessed Hourly Meteorology
Program Options, Receptor and Source Data
Single Source Model
Modeling Results
Hourly Concentrations (Optional)

FIGURE 4-1

PROCEDURE FOR USING THE SINGLE SOURCE (CRSTER) MODEL

Input requirements for the Single Source (CRSTER) Model include the meteorological data tape output by the Preprocessor program, receptor ring distances and terrain elevations, and individual stack data. The stack data items required are source emission rate, stack height, diameter, exit velocity and exit temperature.

The following sections describe the Preprocessor and Single Source (CRSTER) Model programs in detail; their input and output and the requirements for their execution on a UNIVAC 1100 EXEC 8 Operating System. Instructions are also given for executing the programs on an IBM System/360 Operating System.

4.2 PREPROCESSOR PROGRAM

4.2.1 Description

The Preprocessor program generates a magnetic tape of hourly values for the meteorological parameters required by the Single Source (CRSTER) Model, namely wind speed, wind direction, mixing height, stability class and temperature. The input required by the Preprocessor are: (1) hourly National Weather Service (NWS) observations of surface wind speed, wind direction, temperature, cloud cover and ceiling height in magnetic tape format; and (2) daily minimum and maximum mixing heights in punched card format, as determined from NWS 1200 GMT upper air temperature surroundings, using the methods of Holzworth [9]. The Preprocessor, in addition to generating the meteorological data for the Single Source (CRSTER) Model, performs checks for missing data on the tape of hourly surface observations and prints diagnostic messages for any discrepancies that are detected. Quality checks are not performed on mixing height data input to the Preprocessor, and so it is recommended that the user review such data independently.

Data for each day are read by the Preprocessor and processed one hour at a time, using methods described in Section 2.3. The cloud ceiling height, wind speed, ambient temperature, and sky cover data are used to classify the atmospheric stability for each hour. The wind speed is converted from the input units of knots to meters per second, as required by the Single Source (CRSTER)

Model. A flow vector (indicating plume direction) is calculated from hourly mean wind direction data. In addition, a randomized flow vector is computed to account for the natural turbulent fluctuations of the wind, not reflected in the hourly mean observation. Hourly mixing heights for both rural and urban conditions are derived from the morning (daily minimum) and afternoon (daily maximum) mixing height data.

The Preprocessor program is written in FORTRAN V language for execution on a UNIVAC 1100 Series Operating System and is compatible with most FORTRAN IV compilers on other types of computers. A program source code listing for the Preprocessor is included in Appendix A. Figure 4-2 is a flow diagram of the functions performed by the Preprocessor.

4.2.2 Control Language and Data Deck Setup

a. Control Language Requirements. The following runstream illustrates the Executive Control Language (ECL) required to execute the Preprocessor program on the RTCC UNIVAC 1100:

```
@RUN,priority jobid,account,userid,time
@ASG,A  prog-file
@ASG,A  cd144-file
@USE    8,cd144-file
@ASG,CP met-file
@USE 9, met-file
@XQT    prog-file.PREP
card input deck
@FIN
```

where:

priority = job priority
jobid = six-character job identification
account = user account number
userid = user identification code
time = time requirement for executing the job
prog-file = name of program file containing the Preprocessor absolute element
cd144-file = the file name assigned to the input data file of hourly meteorology in card deck 144 format
met-file = name to be assigned to the output file of combined hourly surface and upper air meteorological data
card input deck = the initialization card followed by the set of mixing height cards.

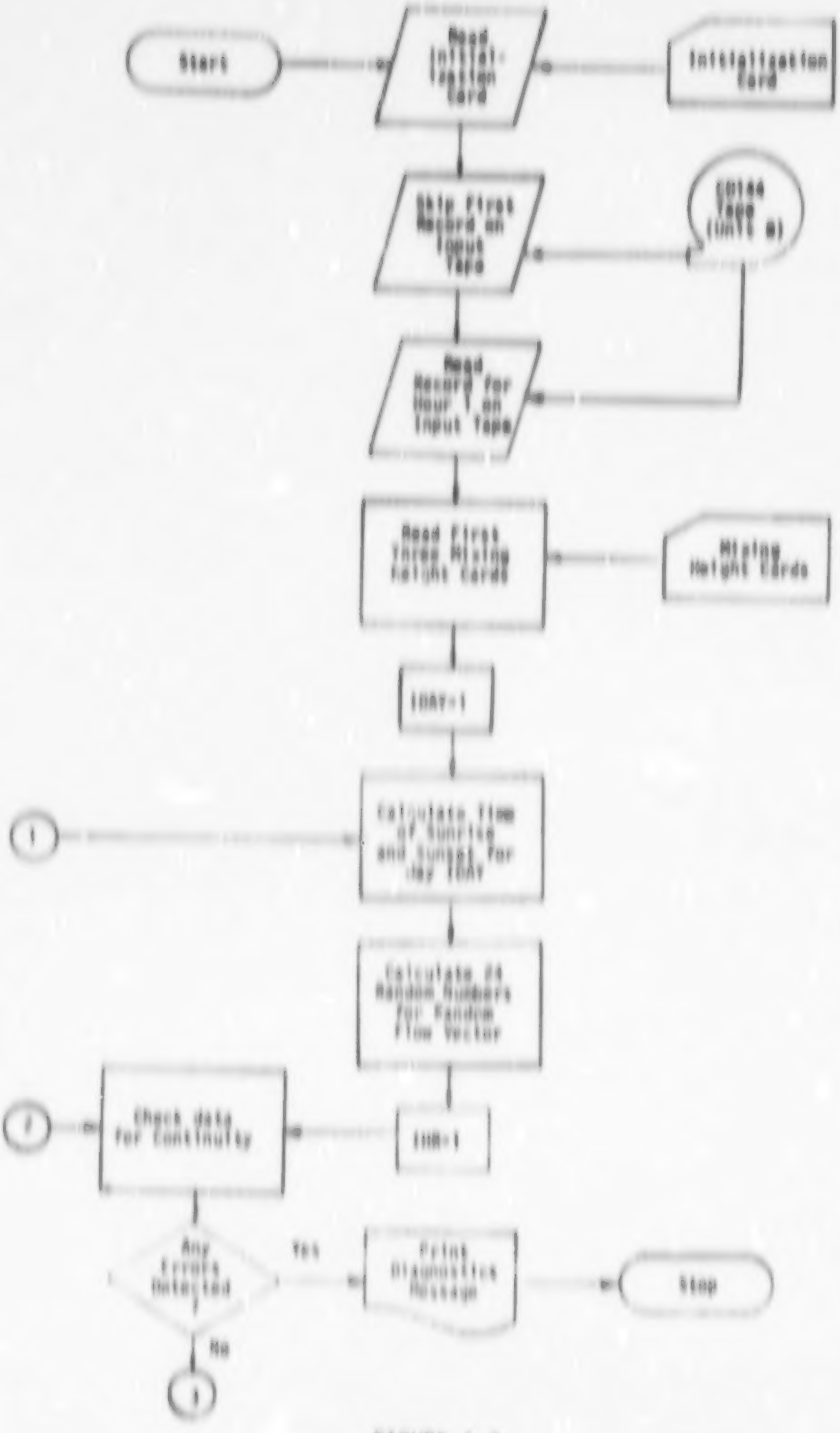

Start
Read Initialization Card
Initialization Card
Skip First Record on Input Tape
CD144 Tape (Unit 8)
Read Record for Hour 1 on Input Tape
Read First Three Mixing Height Cards
Mixing Height Cards
IDAY=1
1
Calculate Time of Sunrise and Sunset for Day IDAY
Calculate 24 Random Numbers for Random Flow Vector
2
Check data for Continuity
IHR=1
Any Errors Detected ?
Yes
Print Diagnostics Message
Stop
No

FIGURE 4-2

PREPROCESSOR PROGRAM FLOW DIAGRAM

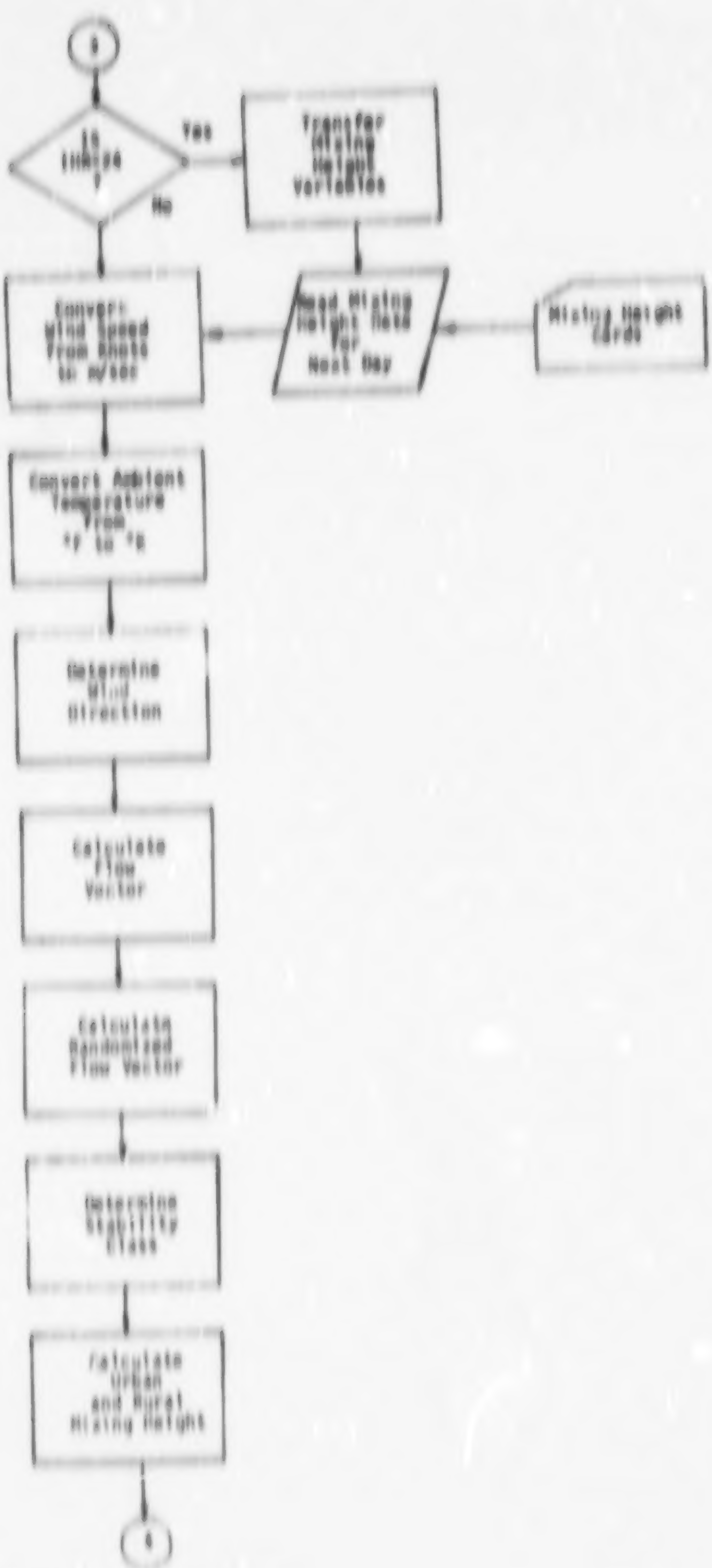

3
Is IHR=24 ?
Yes
No
Transfer Mixing Height Variables
Convert Wind Speed From Knots to m/sec
Read Mixing Height Data For Next Day
Mixing Height Cards
Convert Ambient Temperature From °F to °K
Determine Wind Direction
Calculate Flow Vector
Calculate Randomized Flow Vector
Determine Stability Class
Calculate Urban and Rural Mixing Height
4

FIGURE 4-2 (Continued)

PREPROCESSOR PROGRAM FLOW DIAGRAM

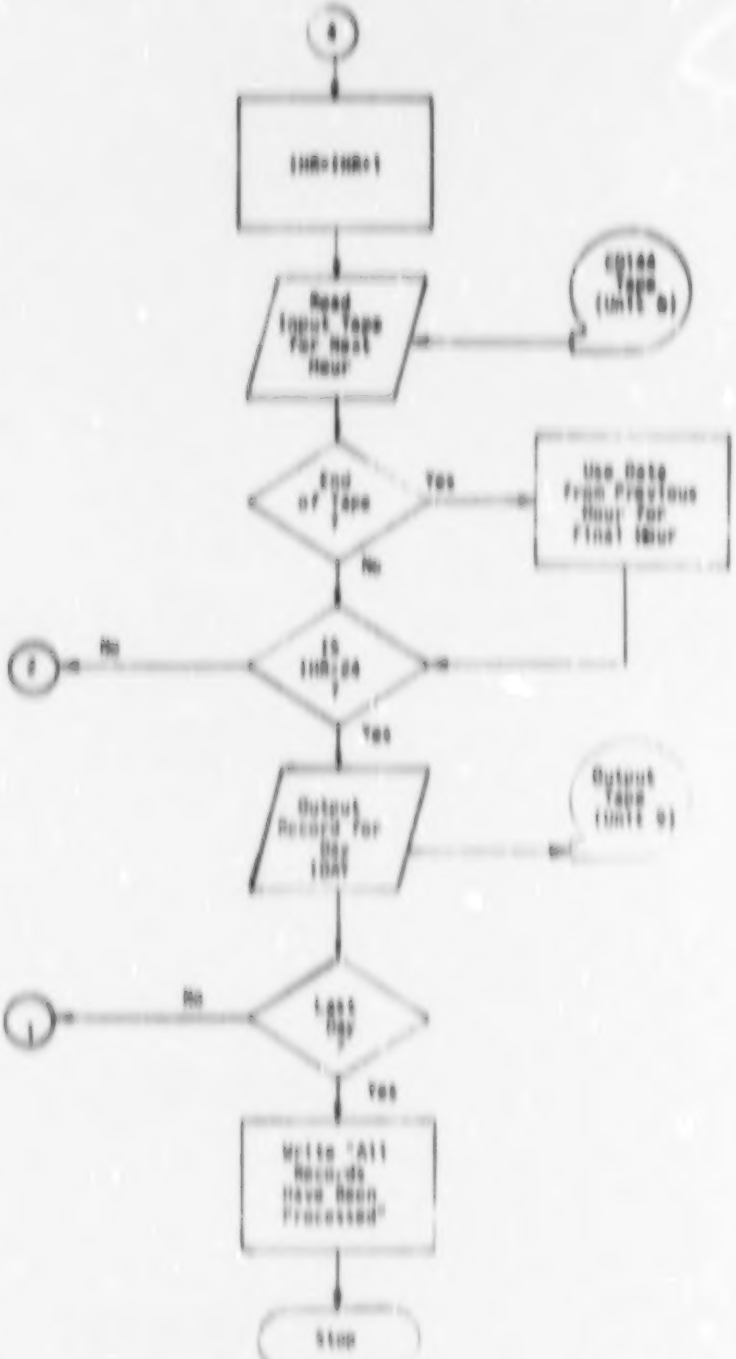

4
IHR=IHR+1
Read Input Tape For Next Hour
CD144 Tape (Unit 8)
End of Tape ?
Yes
Use Data From Previous Hour For Final Hour
No
Is IHR=24 ?
No
2
Yes
Output Record for Day IDAY
Output Tape (Unit 9)
Last Day ?
No
1
Yes
Write "All Records Have Been Processed"
Stop

FIGURE 4-2 (Continued)

PREPROCESSOR PROGRAM FLOW DIAGRAM

The following IBM Job Control Language (JCL) is required to compile, link-edit and execute the Preprocessor program on an IBM System/360 Operating System:

```
//jobno JOB (account),'name',TIME=time
//EXEC FORTGCLG,COND=(4,LT)
//FORT.SYSIN DD *
source deck
//GO.FT08F001 DD DSN=CD144,UNIT=2400,VOL=SER=xxxxxx,DISP=OLD,
//LABEL=(,NL),DCB=(RECFM=FB,LRECL=80,BLKSIZE=800)
//GO.FT09F001 DD DSN=met-file,UNIT=2400,DISP=(NEW,KEEP),
//VOL=SER=yyyyyy,DCB=(RECFM=FB,LRECL=775,BLKSIZE=7750)
card input deck
/*
```

where:

jobno = job number

account = accounting information (system dependent)

name = programmer's name

time = estimated CPU time requirement

source deck = the Preprocessor program source deck on cards

xxxxxx = volume serial number of the tape containing the hourly meteorological data file in card deck 144 format

met-file = name to be assigned to the output meteorological data file

yyyyyy = volume serial number of the tape to receive the output data file

card input deck = card input file consisting of the initialization card followed by the set of mixing height cards.

This example assumes that the input will be on a nonlabeled tape with a block size of 800. This is representative of the form in which the data is issued by the National Climatic Center.

The output file in this example is also on tape with a blocking factor of 10 records per block.

b. Data Deck Setup. The data card deck required for input to the Preprocessor must be set up as follows:

- Preprocessor initialization card
- Mixing height card for December 31 of the year preceding the year of record
- Mixing height card for January 1 of the year of record
- Mixing height card for January 2 of the year of record

•

•

•

- Mixing height card for December 30 of the year of record
- Mixing height card for December 31 of the year of record
- Mixing height card for January 1 of the year following the year of record

The Preprocessor initialization card contains vaules for data items that must be initialized for each run. The mixing height cards contain the morning and afternoon mixing heights for the corresponding day. The methodology for calculating hourly mixing heights from the twice daily mixing heights involves interpolations using the afternoon mixing height from the preceding day and both mixing heights from the following day. For this reason, the mixing heights for the last day of the year preceding the year of record must be included as the first mixing height card and the mixing heights for the first day of the year following the year of record must be included as the last mixing height card. If these data are not available, the data for the first and last days of the year of record can be substituted, respectively. The contents and formats of the Preprocessor initialization card and mixing height cards are described below.

4.2.1 Input Data Description

a. Card Input. Card input requirements for the Preprocessor consist of an initialization card followed by a set of mixing height cards. Coding forms for preparing the Preprocessor card input data are included in Appendix C.

The Preprocessor initialization card contains information to initialize the following items:

: NWS meteorological surface station number
: Year of record
: Latitude of the surface station
: Longitude of the surface station
: Time zone of the surface station
: Number of days in the year
: Initial value for generating random numbers

Table 4-1 is a description of the format of the initialization card.

The set of mixing height cards is composed of one card for the last day of the year preceeding the year of record, one card for each day of the year of record, and one card for the first day of the next year. Each card contains the NWS upper air station number, the date and values for the morning and afternoon mixing heights. Table 4-2 is a description of the format for the mixing height cards. The twice daily mixing height cards must be punched up from either magnetic tape or printed tabular data for an appropriate NWS upper air station in the year of record, which can be purchased from the National Climatic Center (NCC), Asheville, North Carolina. This tape stores one day of data per 34-character record using the format shown in Table 4-3, with 10 records to a block. *Note that the afternoon mixing height column numbers on the NCC tape are not the same as those required on the Preprocessor mixing height data cards.*

b. *Tape Input Requirements*. A magnetic tape containing card images of the hourly meteorological data in "Card Deck 144 format" required by the Preprocessor can be purchased from the NCC. These data can also be purchased as 8,784 punched cards. Each tape data file contains one card image record for each hour. The format of these records is described in the *Card Deck 144 WBAN Hourly Surface Observations Reference Manual* [17]. Data on this file used by the Preprocessor includes the station number, year, month, day, hour, cloud ceiling height, wind direction, wind speed, dry bulb temperature, and sky cover. When ordering tapes to be processed on a UNIVAC computer, a blocking factor of one record per block should be specified.

TABLE 4-1
PREPROCESSOR INITIALIZATION CARD FORMAT

Card Columns	Format	Description
1-5	I5	NWS Surface Station WBAN Number
6-7	I2	Year of Surface Data
8		Blank
9-18	F10.1	Latitude of the Surface Station (degrees to hundredths)
19-28	F10.1	Longitude of the Surface Station (degrees to hundredths)
29-30	F2.0	Time zone in which the Surface Station is located: 05 = Eastern 06 = Central 07 = Mountain 08 = Pacific
31-34	I4	Number of days in the year of record (365 for non leap years; 366 for leap years)
35-44	F10.0	Random Number Seed *

*__NOTE__: The user is cautioned with regard to the random number generator used in the preprocessor program. The subroutine called in this program is entitled RANDN and is provided by Sperry Rand Corporation for use on the Environmental Protection Agency's Univac 1110. There is no computer code available, therefore, requiring the user to contact his systems personnel about a suitable alternative. Because the same random number generator will not be used by all users, the randomized flow vectors may differ when comparing preprocessor file results from two different computers.

TABLE 4-2
PREPROCESSOR MIXING HEIGHT DATA CARD FORMAT

Card Column	Format	Description
1-5	I5	NWS Upper Air Station WBAN Number
6-7	I2	Year of record (last two digits)
8-9	I2	Month
10-11	I2	Day
12	1X	Blank
13-17	F5.0	Morning Mixing Height (m)
18-30	13X	Blank
31-35	F5.0	Afternoon Mixing Height (m)

TABLE 4-3

DATA RECORD FORMAT FOR NCC MAGNETIC TAPES OF MORNING AND AFTERNOON MIXING HEIGHTS

Record Positions	Format	
1-5	I5	NWS Upper Air Station WBAN Number
6-7	I2	Year of record (last two digits)
8-9	I2	Month
10	I1	Season (1 = Dec.-Feb., 2 = Mar.-May, 3 = June-Aug., 4 = Sept.-Nov.)
11-12	I2	Day
13	A1	Type Code (P = precipitation, C = morning average temperature plus 5°C is less than 1200 GMT surface temperature, M = missing)
14-17	I4	Morning Mixing Heights (m)
18-20	I3	Morning* Surface Wind Speed (m s^{-1})
21-23	I3	Morning Wind Speed Averaged from Surface through Mixing Height (m s^{-1})
24	A1	Type Code (P = precipitation, C = afternoon average temperature is less than 1200 GMT surface temperature, M = missing)
25-28	I4	Afternoon Mixing Height (m)
29-31	I3	Afternoon** Surface Wind Speed (m s^{-1})
32-34	I3	Afternoon Wind Speed Averaged from Surface through Mixing Height (m s^{-1})

* 0200-0600 LST

** 1200-1600 LST

If data for an NWS surface observation station have not been processed into tape format by the NCC, the data can be coded from printed copies of the WBAN Form A observations, also available from NCC. Instructions for coding the data in Card Deck 144 format are given in the Card Deck 144 Reference Manual [17]. Only the items required by the Preprocessor need to be coded.

4.2.4 Output Data Description

The output tape from the Preprocessor consists of a sequential file containing a file identification record followed by one record for each day in the year.

The file identification record contains the year of record for the surface meteorological data, the surface station identification number, the year of record for the mixing height data, and the upper air station identification number.

Each of the daily records contain the year, month, and the julian day followed by 24 values of stability class, wind speed, temperature, flow vector, randomized flow vector, and rural and urban mixing heights. Because the last record on the input tape corresponds to the 23rd hour of the last day, the data for that hour is also used for the 24th hour on the last record on the output tape.

All records on the output file are written with an unformatted FORTRAN write statement. The output files, therefore, are machine dependent and cannot be directly accessed by the Single Source (CRSTER) Model on systems different from the computer creating the file.

The four parameters on the file identification record and the year, month and stability class on each of the daily records are stored as FORTRAN integer varibles. All other values on the daily records are FORTRAN real number variables. Table 4-4 is a description of the arrangement of the variables on each of the daily records.

Assuming no fatal error messages, the entire Preprocessor file is printed and successful run completion is indicated by the message:

ALL RECORDS HAVE BEEN PROCESSED

TABLE 4-4

PREPROCESSOR OUTPUT FILE RECORD DESCRIPTION

Position of Variable Within the Record	Variable Name	Fortran Variable Type	
1	IYEAR	INTEGER	Year of record (last two digits)
2	IMONTH	INTEGER	Month
3	DAY1	REAL	Day of month
4-27	KST	INTEGER	Array of 24 Stability Class Values
28-51	SPEED	REAL	Array of 24 Wind Speed Values (ms^{-1})
52-75	TEMP	REAL	Array of 24 Ambient Temperature Values (°K)
76-99	AFV	REAL	Array of 24 Flow Vector Values (degrees)
100-123	FVR	REAL	Array of 24 Randomized Flow Vectors (degrees)
124-171	HLH	REAL	Array dimensioned 2 by 24 containing 24 rural mixing height values and 24 urban mixing height values (m). The values are stored on the record in groups of two for each hour with the rural mixing height first followed by the urban mixing height for that hour.

4.2.5 Diagnostic Messages

Two types of diagnostics may be generated by the Preprocessor program namely, fatal error messages and informative messages.

Fatal error messages are printed when an inconsistency is detected in the input data, causing the program to stop execution. Table 4-5 is a list of all possible fatal error messages and the corrective action that should be taken.

Informative messages are printed when anomalous data items are detected. No user action is necessary in response to an informative message unless the assumptions made by the program adversely affect the results. Table 4-6 is a list of the informative messages in the Preprocessor program.

4.3 SINGLE SOURCE (CRSTER) MODEL

4.3.1 Description

The Single Source (CRSTER) Model is a computer program that applies a modified form of the Gaussian plume equation in calculating the contributions to ambient air quality levels from a single plant with up to 19 individual stacks. The model calculates concentrations for an entire year (calculations can optionally be restricted to only selected days) and prints out the highest 1-hour, 3-hour, 24-hour, as well as annual average, concentrations at a set of 180 receptors surrounding the plant. In addition, concentrations can be obtained for a variable averaging period which can be selected as 2, 4, 6, 8 or 12 hours. The Single Source (CRSTER) Model predicts pollutant concentrations for each hour at a series of 5 ring distances and at 36 wind direction azimuths (every 10°), based on hourly values of wind speed, direction, stability class and mixing height. The model can optionally produce output for individual stack contributions to concentrations at selected receptor points for any averaging period. The model can also generate a tape file of hourly, daily and annual concentrations at each receptor point.

TABLE 4-5

PREPROCESSOR FATAL ERROR MESSAGES

ID DOES NOT MATCH IN RECORD # i ID ON TAPE IS n ID REQUESTED IS k
*****DATA IS MISSING. PLEASE CORRECT INPUT FILE*****[1]

Description:	This message is printed if the surface station identification entered on the Preprocessor initialization card does not match the station number on a record in the hourly meteorological data file. The value i is the number of the record within the file, n is the station number on the record, and k is the station number requested.
Action:	If n = 1, check the surface station number input on the Preprocessor initialization card and the input meteorological data file to be sure that the correct file was input. If n > 1, the input file is bad. A listing of the file should be inspected to determine what corrective action is necessary.

YEAR IS i INSTEAD OF j IREC = n

Description:	The year i on record number n of the meteorological data file did not match the year j input on the Preprocessor initialization card.
Action:	If n = 1, check to be sure that the correct year was entered on the Preprocessor initialization card and that the correct input file was used. If n > 1, the data file is in error. A listing of the file should be inspected to determine what corrective action is necessary. If n > 8,760, check to be sure the number of days entered on the Preprocessor initialization card is correct.

---

[1] This line appears on fatal error messages for ID, YEAR, MONTH, DAY, HOUR

TABLE 4-5 (CONTINUED)

PREPROCESSOR FATAL ERROR MESSAGES

MONTH i DOES NOT AGREE WITH LOOP j IREC = n

Description: The month i on input record n of the meteorological data file is out of sequence. The month should have been number j.

Action: If i = 2 and j = 3, check to be sure the number of days entered on the Preprocessor initialization card was 365 for a non-leap year. If i = 3 and j = 2, check to be sure that the number of days entered on the Preprocessor initialization card was 366 for a leap year. If the number of days input was incorrect, enter the appropriate value and rerun Preprocessor. Otherwise, inspect a listing of the input file for missing or extraneous records. If the file is out of order, sort the file in ascending order keying on columns 1-13.

DAY i DOES NOT AGREE WITH LOOP j IREC = n

Description: The day i on input record n of the meteorological data file is out of sequence. The day should have been number j.

Action: Inspect a listing of the input file for missing or extraneous records. If the file is out of order, sort the file in ascending order keying on columns 1-13.

HOUR i DOES NOT AGREE WITH LOOP j IREC = n

Description: The hour i on record n of the input meteorological data file was out of sequence. The hour expected was hour j. This message is printed for hours 1 through 23, for which the value on the input record should equal the value of the index of the hourly 'DO' loop.

Action: Inspect a listing of the input file for missing or extraneous records. If the file is out of order, sort the file in ascending order keying on columns 1-13.

TABLE 4-5 (CONTINUED)
PREPROCESSOR FATAL ERROR MESSAGES

ERROR: MISSING HOUR LOOP VALUE = j WHILE VALUE ON RECORD n IS i

Description:	This message is printed if the last hour of the day being processed (j = 24) is not the data for the first record of the next day (i = 0).
Action:	Inspect a listing of the meteorological data file for missing or extraneous records. If the file is out of order, sort the file, keying on columns 1-13.

TABLE 4-6
PREPROCESSOR INFORMATIVE MESSAGES

THE CHARACTER x IS NOT ALLOWABLE ; CLOUD COVER DEFAULTS TO 10.

Description: The cloud cover on a record in the input meteorological data file was value x. The only valid values for cloud cover are 0,1,2,3,4,5,6,7,8,9 or -. The program assumes a value of "-" which is interpreted as a 10 tenths cloud cover.

STABILITY = i j r n

Description: A stability class was assigned an invalid value (i). The value j is the wind speed index, r is the net radiation index number, and n is the number of the input meteorological data file record being processed.

The Single Source (CRSTER) Model is written in FORTRAN V language for execution on a UNIVAC 1100 series computer and is compatible with most FORTRAN IV compilers on other types of computers. The Single Source (CRSTER) Model is composed of a main program (CRSV), three subroutines (CRS, BEHO72, and SIGMA), and a block data common storage area. The source code for each of these program elements is listed in Appendix A.

The CRSV program is responsible for reading and checking the card input data, and checking that the correct preprocessed meteorological data file was assigned to the run. If any errors in the input data are detected, a diagnostic message is printed and the program execution is terminated. Otherwise, the program calls the CRS subroutine to perform the dispersion modeling and output the results, after which control is returned to CRSV and execution is terminated. Figure 4-3 is a flow diagram of the CRSV program.

The CRS subroutine calculates hourly concentrations at each receptor, derives the information described previously, and outputs summary tables and source contribution tables. Figure 4-4 is a flow diagram of the CRS subroutine described below. First, the SIGMA subroutine is called by CRS to calculate an estimate of the horizontal (σ_y) and vertical (σ_z) dispersion coefficients for each combination of distance and stability class. These values are stored in an array for use in the dispersion calculations. The program then reads the hourly meteorology for each day and calculates the concentration for each stack at each receptor point. Plume rise estimates are computed by the BEHO72 subroutine. The concentrations from each stack are summed to form plant totals which are averaged over each 1-hour, 3-hour and 24-hour time interval. If a variable averaging time was specified (2, 4, 6, 8 or 12 hours), the average concentrations for each time interval of that length are also computed. As calculations for each day are completed, the daily concentrations are added to the annual total, and the average concentrations are checked for maxima. If requested, the individual stack contribution to the concentrations at selected receptor points are listed. When the last day in the meteorological data file has been processed, the summary tables for each averaging period are printed and control is returned to the CRSV program. If source contributions have been requested, these summary tables are not printed.

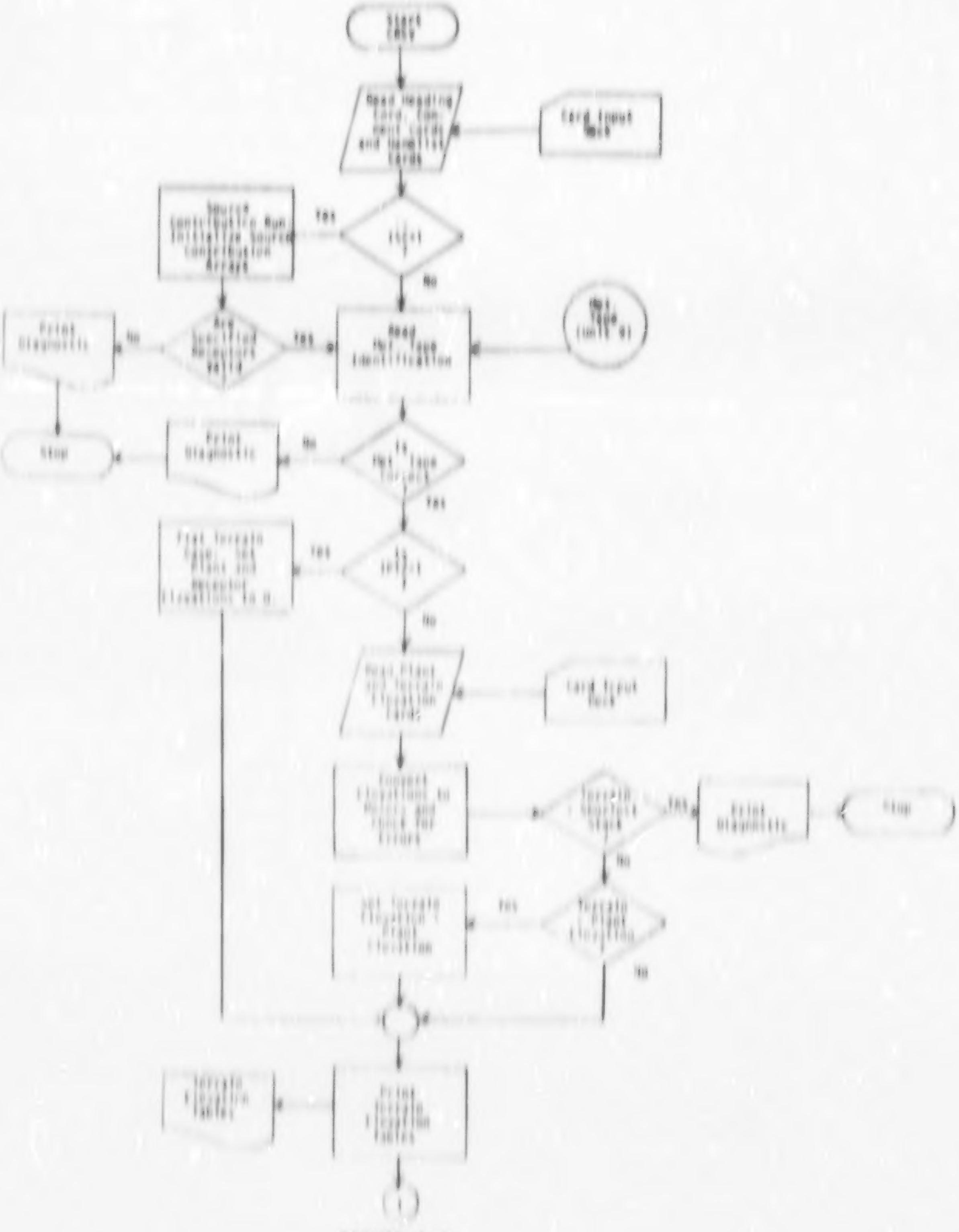

Start
CRSV
Read Heading
Card
and
Cards
Card Input
Deck
Source
Contribution Run;
Initialize Source
Contribution
Arrays
Yes
No
Are
Specified
Receptors
Valid
?
Print
Diagnostic
Read
Met Tape
Identification
Met
Tape
(Unit 8)
Stop
Is
Met Tape
Correct
?
Flat Terrain
Case; Set
Plant and
Receptor
Elevations to 0.
Read Plant
and Terrain
Elevation
Cards
Card Input
Deck
Convert
Elevations to
Meters and
Check for
Errors
Terrain
> Shortest
Stack
?
Terrain
> Plant
Elevation
?
Set Terrain
Elevation =
Plant
Elevation
Terrain
Elevation
Tables
Print
Terrain
Elevation
Tables
1

FIGURE 4-1

CRSV PROGRAM FLOW DIAGRAM

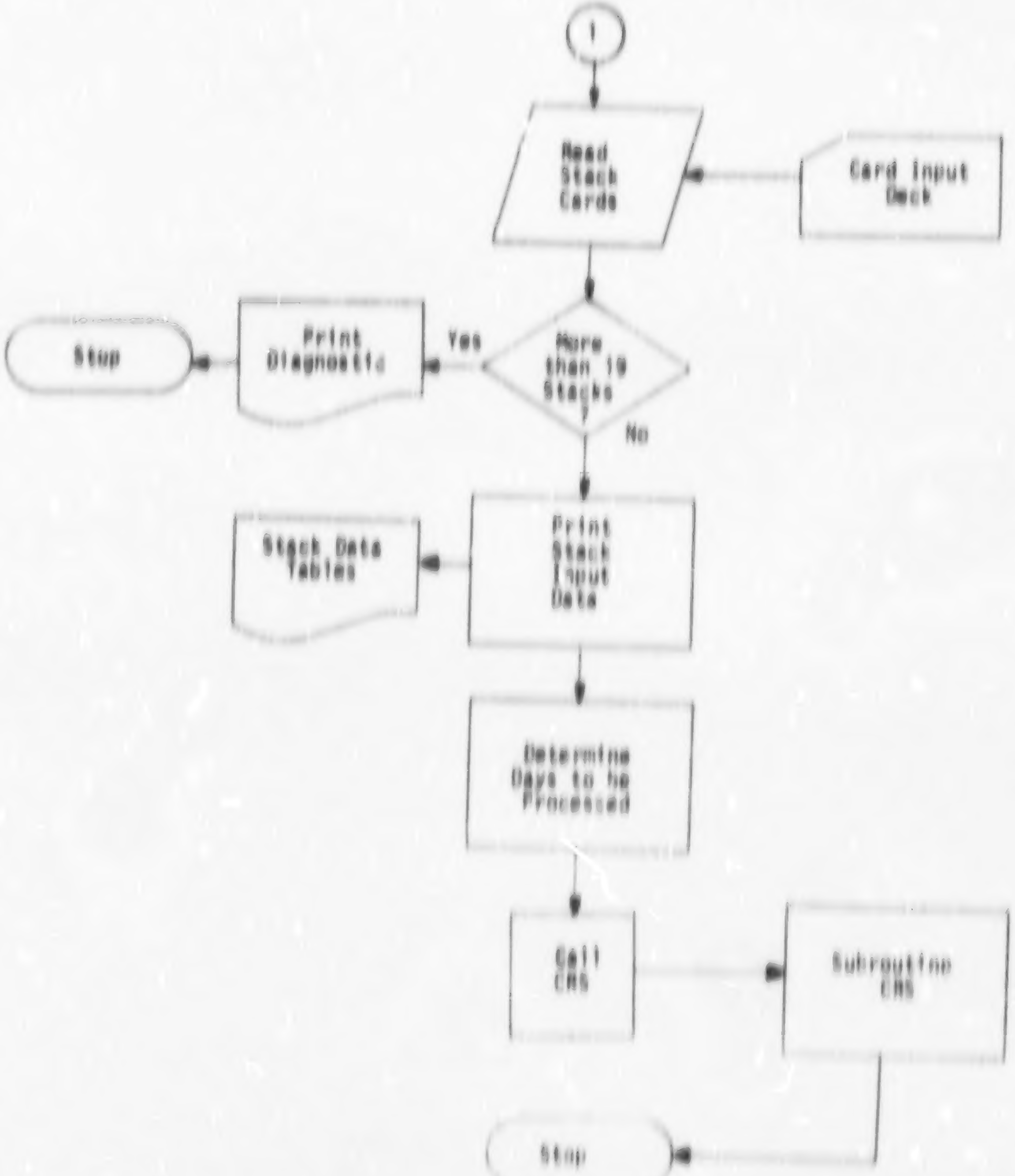

1
Read Stack Cards
Card Input Deck
More than 19 Stacks ?
Yes
No
Print Diagnostic
Stop
Print Stack Input Data
Stack Data Tables
Determine Days to be Processed
Call CRS
Subroutine CRS
Stop

FIGURE 4-3 (Continued)

CRSV PROGRAM FLOW DIAGRAM

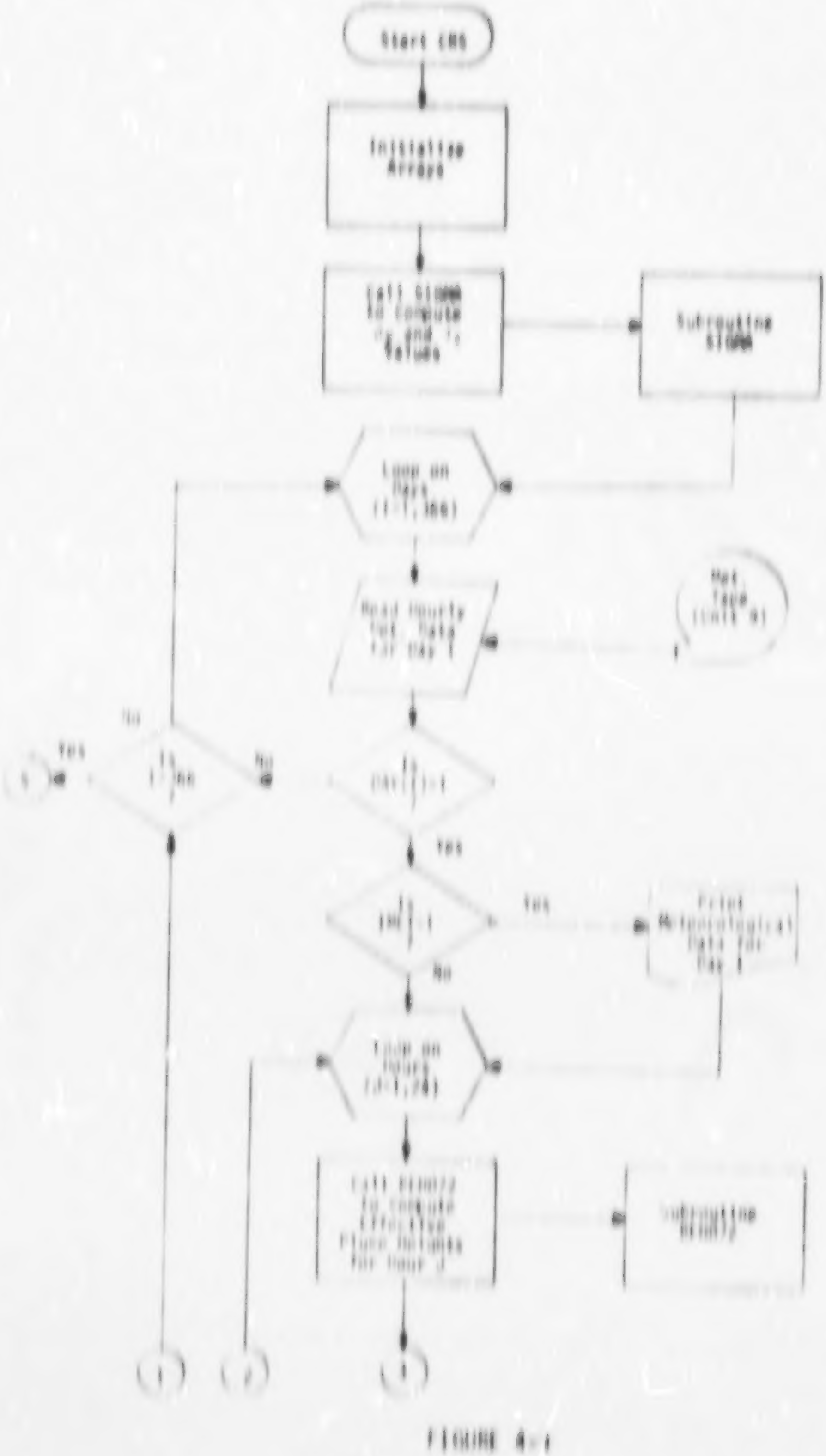

Start CRS
Initialize Arrays
Call SIGMA to Compute σy and σz Values
Subroutine SIGMA
Loop on Days (I=1,366)
Read Hourly Met. Data for Day I
Met. Tape (Unit 9)
No
Yes
Is I>365
No
Yes
Yes
Print Meteorological Data for Day I
No
Loop on Hours (J=1,24)
Call HIGHT2 to Compute Effective Plume Heights for Hour J
Subroutine HIGHT2
1
2
3

FIGURE 4-1

SUBROUTINE CRS FLOW DIAGRAM

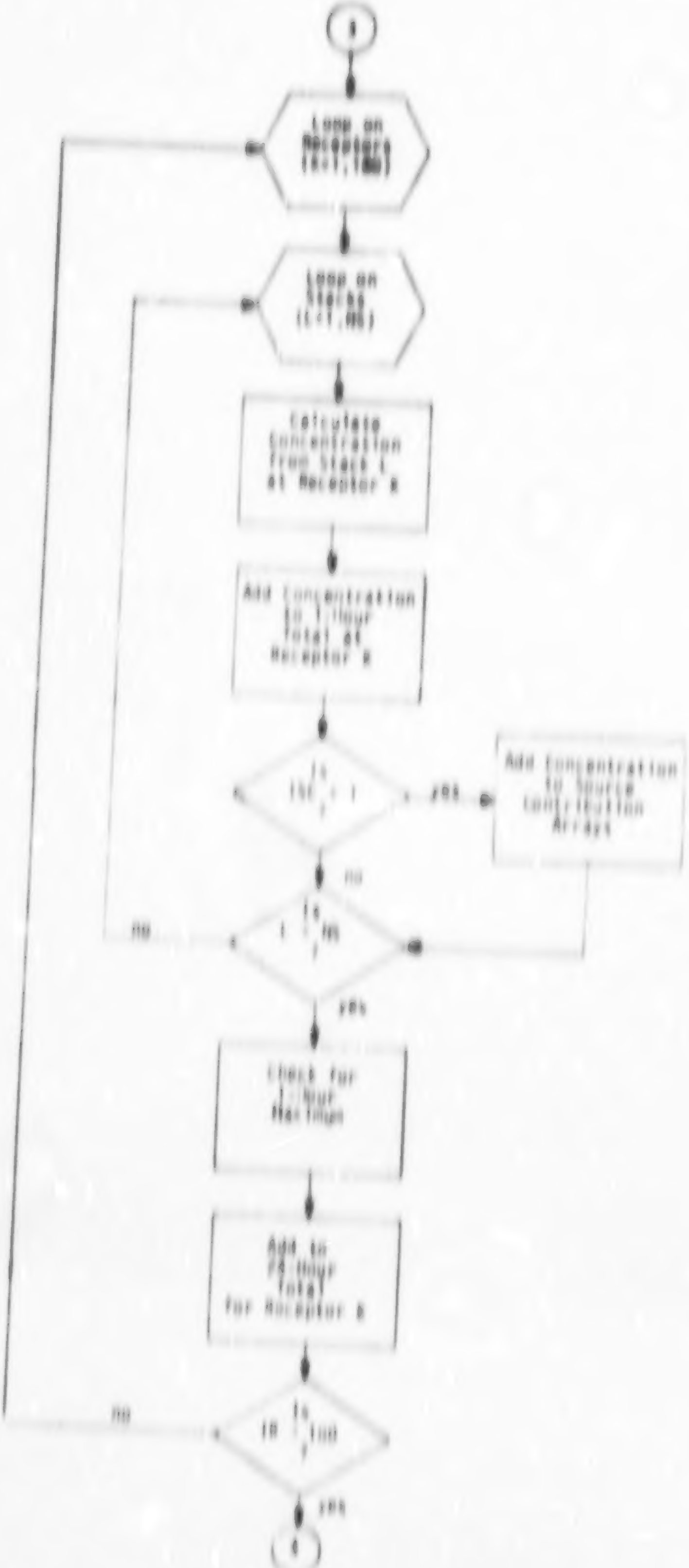

Loop on
Receptors
(K=1,180)
Loop on
Stacks
(L=1,NS)
Calculate
Concentration
from Stack L
at Receptor K
Add Concentration
to 1-Hour
Total at
Receptor K
Is
ISC = 1
yes
Add Concentration
to Source
Contribution
Arrays
no
Is
L = NS
no
yes
Check for
1-Hour
Maximum
Add to
24-Hour
Total
for Receptor K
no
Is
IR = 180
yes

FIGURE 4-4 (Continued)
SUBROUTINE CRS FLOW DIAGRAM

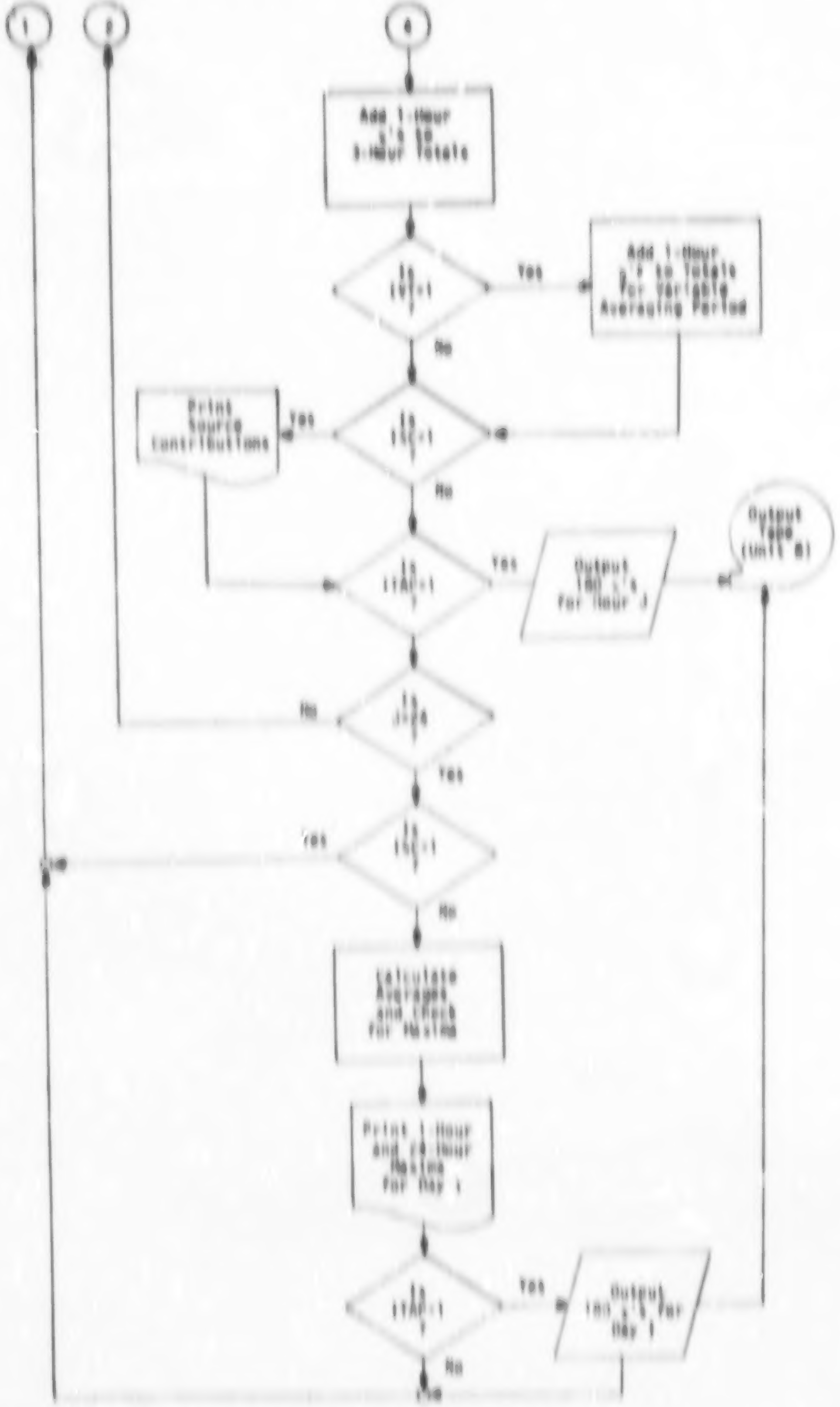

1
2
4
Add 1-Hour χ's to 3-Hour Totals
Is IVT=1 ?
Yes
Add 1-Hour χ's to Totals for Variable Averaging Period
No
Print Source Contributions
Yes
Is ISC=1 ?
No
Is ITAP=1 ?
Yes
Output 180 χ's for Hour J
Output Tape (Unit 8)
No
Is J=24 ?
Yes
Yes
Is ISC=1 ?
No
Calculate Averages and Check for Maxima
Print 1-Hour and 24-Hour Maxima for Day I
Is ITAP=1 ?
Yes
Output 180 χ's for Day I
No

FIGURE 4-4 (Continued)

SUBROUTINE CRS FLOW DIAGRAM

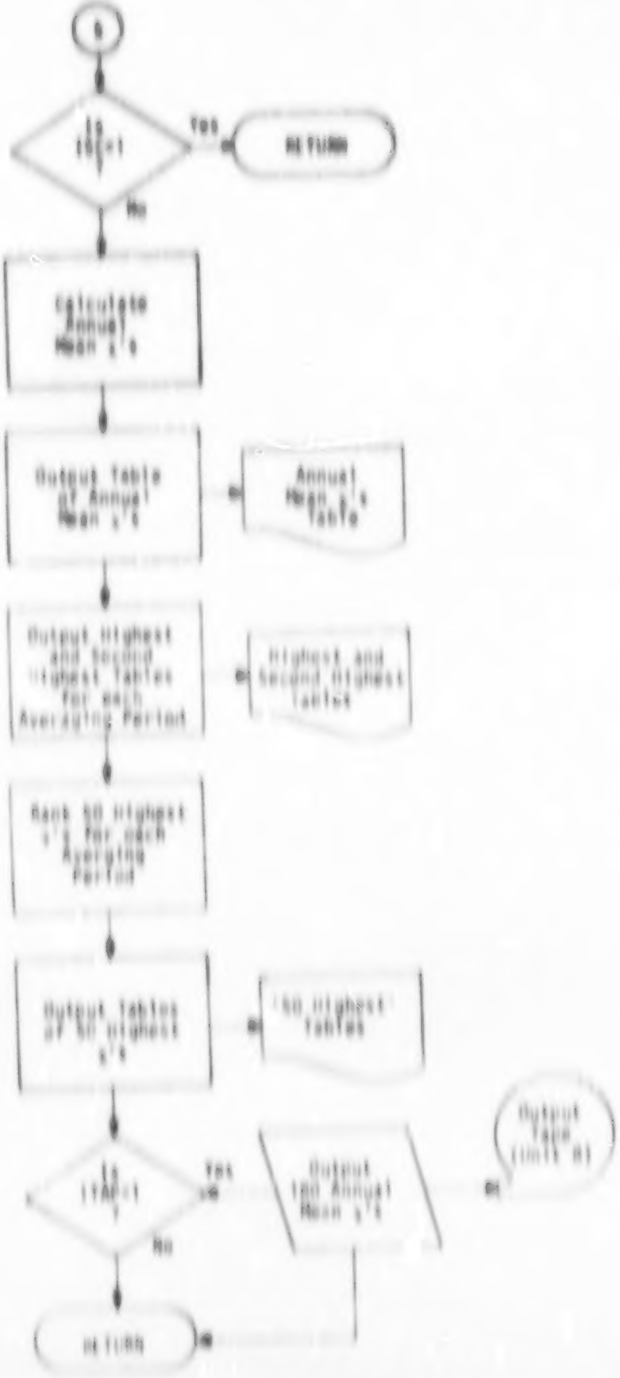

B
Is IST=1 ?
Yes
RETURN
No
Calculate Annual Mean χ's
Output Table of Annual Mean χ's
Annual Mean χ's Table
Output Highest and Second Highest Tables for each Averaging Period
Highest and Second Highest Tables
Rank 50 Highest χ's for each Averaging Period
Output Tables of 50 Highest χ's
50 Highest Tables
Is ITAP=1 ?
Yes
No
Output 100 Annual Mean χ's
Output Tape (Unit 8)
RETURN

FIGURE 4-4 (Continued)

SUBROUTINE CRS FLOW DIAGRAM

The SIGMA subroutine computes σ_y and σ_z for a given downwind distance and atmospheric stability class. The program uses a set of equations, derived from the family of dispersion curves shown in figures 2-1 and 2-2. Figure 4-5 is a flow diagram of the SIGMA subroutine. Arguments that are passed to the SIGMA subroutine are the downwind distance (km) of the receptor from the source and the atmospheric stability class number (a value from 1 through 6 corresponding to Pasquill stability classes A through F, respectively). The program returns values of σ_y and σ_z in meters.

The BEH072 subroutine calculates an effective plume height using the Briggs plume rise equations (see Section 2.2.5). Figure 4-6 is a flow diagram of the BEH072 subroutine. Arguments that must be passed to this subroutine are physical stack height (m), stack diameter (m), stack gas exit velocity (m s^{-1}), stack temperature (°K), atmospheric stability class (a value from 1 through 6 corresponding to Pasquill stability class A-F), wind speed (m s^{-1}), downwind distance (km), potential temperature lapse rate (°K m^{-1}), ambient air temperature (°K) and ambient pressure (mb). The program returns the value of the final effective plume height in meters. Other parameters calculated by BEH072 but not used by CRS include effective plume height at the given downwind distance (m), power output of the source (MW), bouyancy flux (m^4 s^{-3}) and final plume rise (m).

The block data common storage area is needed to initialize variables in common storage using FORTRAN DATA statements.

4.3.2 Control Language and Data Deck Setup

a. Control Language Requirements. The following runstream illustrates the ECL commands required to execute the Single Source (CRSTER) Model on a UNIVAC 1100 Series Operating System:

```
@RUN,priority jobid,account,userid,time
@ASG,A prog-file
@ASG,A met-file
@USE 9, met-file
@ASG,CP output-file }
@USE 8,output-file  }- Optional, required only if ITAP=1
@XQT prog-file.SSM
card input deck
@FIN
```

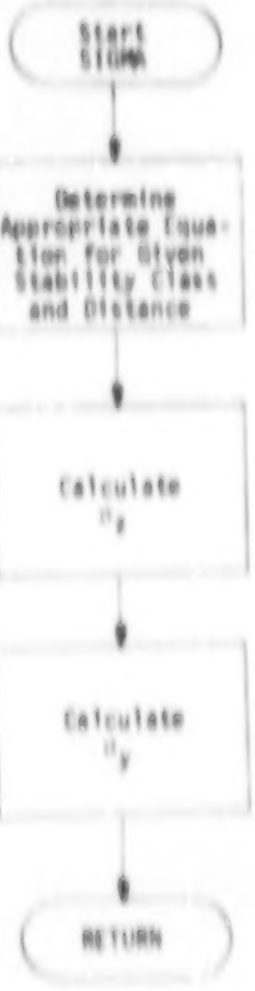

Start SIGMA
Determine Appropriate Equation for Given Stability Class and Distance
Calculate σ_z
Calculate σ_y
RETURN

FIGURE 4-5

SUBROUTINE SIGMA FLOW DIAGRAM

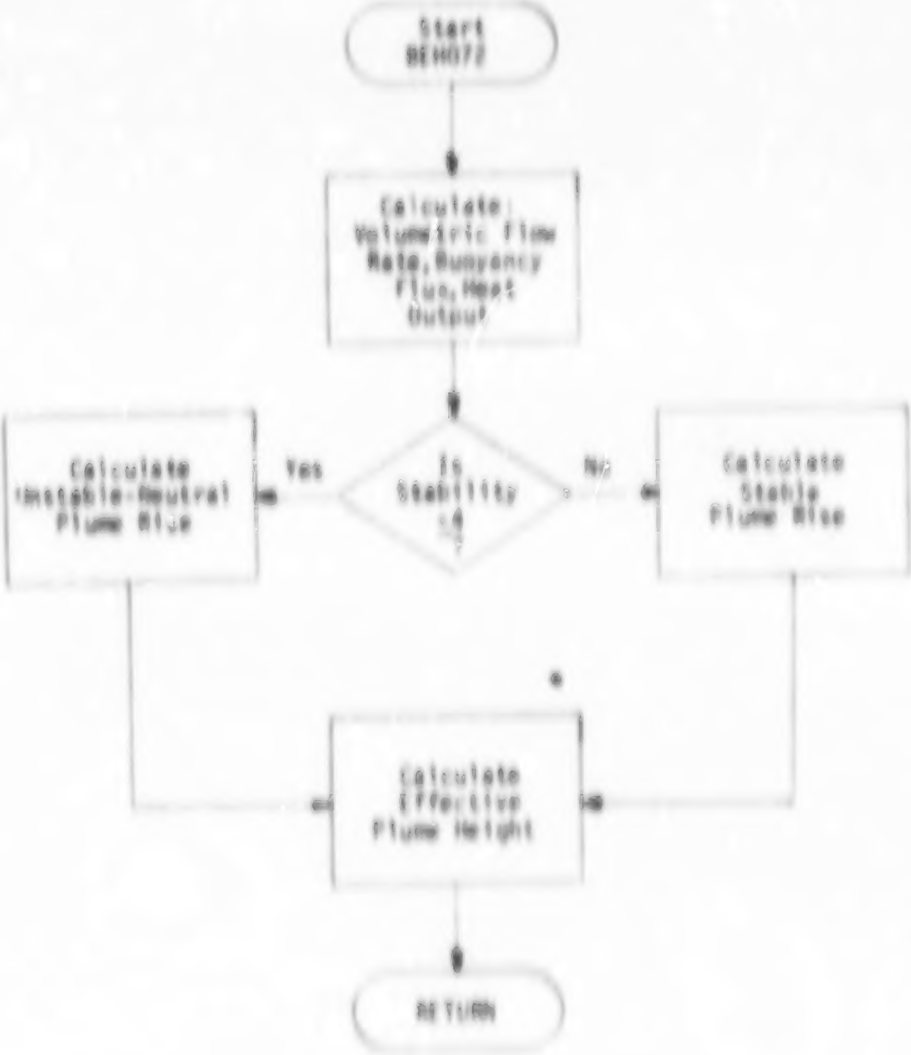

Start
BEH072
Calculate:
Volumetric Flow
Rate,Buoyancy
Flux,Heat
Output
Is
Stability
≤4
?
Yes
No
Calculate
Unstable-Neutral
Plume Rise
Calculate
Stable
Plume Rise
Calculate
Effective
Plume Height
RETURN

FIGURE 4-6

SUBROUTINE BEH072 FLOW DIAGRAM

where:

priority = job priority

jobid = six-character job identification

account = account number

userid = six-character user identification code

time = execution time requirements

prog-file = name of the program file containing the Single Source (CRSTER) Model absolute element

met-file = name of the preprocessed meteorological data file

output-file = name of the file to receive the hourly concentrations

card input data = input data card deck.

The following Job Control Language (JCL) is required to compile, link-edit and execute the Single Source (CRSTER) Model on an IBM System/360 Operating System:

```
//jobno JOB (account),'name',TIME=time
//SSM EXEC FORTGCLG,COND=(4,LT)
//FORT.SYSIN DD *
Single Source Model Source Deck                                   Optional,
//GO.FT08F001 DD DSN=out-file,UNIT=2400,VOL=SER=ssssss,       }   required
//DISP=(NEW,KEEP),DCB=(RECFM=VBS,LRECL=720,BLKSIZE=7200)      }   only if
//GO.FT09F001 DD DSN=met-file,UNIT=2400,DISP=OLD,                 ITAP=1
// VOL=SER=yyyyyy
//GO.SYSIN DD *
card input deck
/*
```

where:

jobno = job number

account = required accounting information

name = programmer's name

time = estimated CPU time requirements

out-file = name of the output file to receive the hourly concentrations

ssssss = volume serial number of tape to receive the hourly concentrations

met-file = name of the preprocessed meteorological data file

yyyyyy = volume serial number of the tape containing the preprocessed meteorological data file.

In this example, the input meteorological data file and the output file on unit 4 are assumed to be tape files. If those data files are to be stored on other devices, appropriate changes must be made to the JCL listed above.

b. Data Deck Set-up. The data card deck required by the Single Source (CRSTER) Model is dependent on the options requested by the user. In general, the input deck must be set up as shown in Figure 4-7 and summarized below:

- Plant Title Card
- Comment Cards (as many as required)
- Delimiter Card (All blanks)
- Namelist NAM1 Cards
- Plant Elevation Card
- Receptor Elevation Cards (36 cards; one for each direction)
- Delimiter Card (All blanks)

  Optional, required only if IPTZ=1
- Stack Data Cards (two cards for each stack; the first card is a stack identification card; the second card contains the necessary stack data). Up to 19 pairs of stack data cards can be input.
- Delimiter Cards (2) (All blanks)

Examples of decks set up for a standard Single Source (CRSTER) Model run and for a source contribution run are included in Appendix B. A description of the format and contents of each card type is given below.

4.3.3 Input Data Description

The data required to execute the Single Source (CRSTER) Model is contained on two files. A card file must be input that contains source and receptor information, and the meteorological data tape generated by the Preprocessor program must be input for the appropriate upper air and surface station combination.

a. Card Input Requirements. The card deck required for input to the Single Source (CRSTER) Model consists of seven types of cards:

- Heading Cards
- Comment Cards
- Delimiter Cards
- Namelist Cards
- Plant Elevation Cards
- Receptor Elevation Cards
- Stack Data Cards

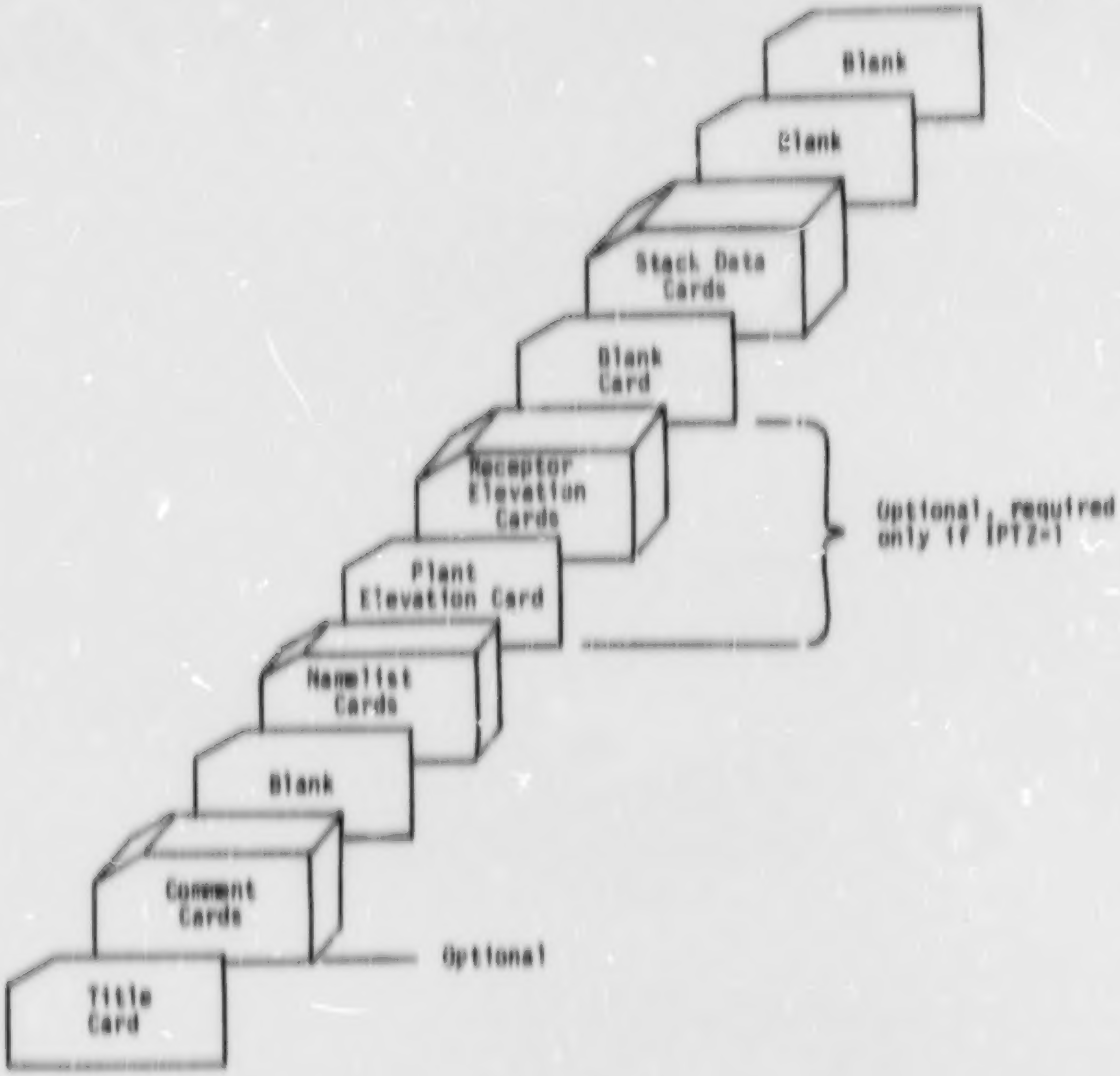

Blank
Blank
Stack Data Cards
Blank Card
Receptor Elevation Cards
Optional, required only if IPTZ=1
Plant Elevation Card
Namelist Cards
Blank
Comment Cards
Optional
Title Card

FIGURE 4-7

INPUT DATA DECK SETUP FOR THE SINGLE SOURCE (CRSTER) MODEL

The heading card contains the plant name in columns 1-24 and pollutant type in columns 25-32. Information on this card is printed on the first line on each page of output.

A set of comment cards follows the heading card. As many comment cards can be included as needed. Each comment consists of 80 alpha-numeric characters. A non-blank character must be included in one of the first four columns. Comment cards are optional. The comments are listed on the first page of printed output.

A blank card serves as a delimiter for card types that are optional or that may be input in various quantities. One delimiter card must follow the last comment card. If no comment cards are input, the delimiter card must follow the heading card. (A delimiter card must also follow the last receptor elevation card if IPTZ=1, and two delimiter cards must follow the last stack data card.)

A set of namelist cards must be included after the comment delimiter card. Table 4-7 is a list of mandatory variables that must be entered in the namelist. Other namelist variables that can be included to select model options are listed in Table 4-8. Table 4-9 is a list of namelist variables that must be assigned values if certain options in Table 4-8 are selected.

The set of namelist cards must be structured as follows:

&NAM1
$name_1=v_1$,$name_2=v_2$,...,$name_i=v_i$,
$name_{i+1}=v_{n+1}$,...
...,$name_n=v_n$, & END

where:

$name_i$ = name of namelist item i
v_i = value to be assigned to variable $name_i$

The first column of each namelist card must be blank. The literal &NAM1 designates the beginning of the namelist input, and must start in column 2 of the first namelist card. The literal &END designates the end of the

TABLE 4-7

MANDATORY NAMELIST VARIABLES

Variable Name	Type	Description
IUR	Integer	1 = rural mixing heights to be used 2 = urban mixing heights to be used
RNG	Real	Array of five receptor ring distances (km)
ISS	Integer	Surface station number for meteorological data
ISY	Integer	Year of record for surface meteorology (last 2 digits)
IUS	Integer	Upper air station number for mixing height data
IUY	Integer	Year of record for mixing height data (last 2 digits)

TABLE 4-8

OPTIONAL NAMELIST VARIABLES

Variable	Type	Description	Default Value
ITAP	Integer	0 = No tape output is to be generated 1 = Hourly and daily concentrations are to be output to tape	0
IPTZ	Integer	0 = Flat terrain case; plant and terrain elevations will be set to 0 1 = Plant and terrain elevations will be input	0
DAY	Integer	Array with dimension 366. Positions 1-366 correspond to the day of the year. Each day assigned a value of 1 will be processed. For non-leap years, DAY(366) must be set to 0.	366*1
IMET	Integer	0 = hourly meteorological data will not be printed 1 = hourly meteorological data will be printed for each day	1
IVT	Integer	Variable averaging time period. Only averaging periods of 2,4,6,8 or 12 hours are permissible. The default of 0 results in no variable averaging period.	0
IQCK	Integer	0 = Monthly emission rates will not be entered. 1 = Monthly emission rates will be input for each stack (Namelist array QSSN must be assigned the emission rate values - see Table 4-9).	0
IVCK	Integer	0 = Monthly stack gas exit velocity values will not be input 1 = Monthly stack gas exit velocity values will be input for each stack. (Namelist array VSSN must be assigned the exit velocity values - see Table 4-9).	0

TABLE 4-8 (Continued)

OPTIONAL NAMELIST VARIABLES

Variable	Type	Description	Default Value
ITCK	Integer	0 = Monthly stack temperature values will not be input 1 = Monthly stack temperature values will be input for each stack (the namelist array TSSN must be assigned the stack temperature values - see Table 4-9).	0
ISC	Integer	0 = Source contribution tables will not be generated 1 = Source contribution tables will be printed for days assigned a value of 1 in the DAY array and the receptors assigned to the namelist arrays SC1, SC3, SCN, SC24 and/or SCAN (see Table 4-9).	0

TABLE 4-9

NAMELIST VARIABLES REQUIRED FOR SPECIFIED OPTIONS

Option Specified	Required Namelist Variable	Type	Description
IQCK=1	QSSN	Real	Twelve monthly emission rate values (g s^{-1}) for each stack.[**]
IVCK=1	VSSN	Real	Twelve monthly exit velocity values (m s^{-1}) for each stack.[**]
ITCK=1	TSSN	Real	Twelve monthly temperature values (°K) for each stack.[**]
ISC=1	SC1[†]	Real	One distance-direction pair[*] for each receptor to be printed in the 1-hourly source contribution table (maximum of 20 pairs).
ISC=1	SC3[†]	Real	One distance-direction pair[*] for each receptor to be printed in the 3-hourly source contribution table (maximum of 20 pairs).
ISC=1 and IVT>0	SCN[†]	Real	One distance-direction pair[*] for each receptor to be printed in the variable averaging time source contribution table (maximum of 20 pairs).
ISC=1	SC24[†]	Real	One distance-direction pair[*] for each receptor to be printed in the 24-hourly source contribution table (maximum of 20 pairs).
ISC=1	SCAN[†]	Real	One distance-direction pair for each receptor to be printed in the annual source contribution table (maximum of 20 pairs).

---

[*] A distance-direction pair is the distance (km) and direction (tens of degrees) of one of the 180 receptors surrounding the plant. The distance must be one of the five ring distances assigned to the namelist array RNG. The direction can have a value from 1 to 36.

[**] Input is an array of 240 numbers, with positions 1-12 corresponding to the monthly stack parameters for stack 1, positions 13-24 for stack 2, etc.

[†] Only one of the namelist variables SC1, SC3, SCN, SC24 and SCAN is required if ISC=1, although all can be specified. (See 4-49)

namelist input and must follow the last value assigned. If necessary, &END can be entered on a separate card, starting in column 2. If a namelist variable is an array, the values can be assigned to the array as follows:

array = $v_1, v_2, \ldots, v_n$,

where:

array = the name of the array

v_i = the value to be assigned to array position i. If n is less than the dimension of the array, only positions 1 through n are assigned values. If a series of contiguous array positions are to be assigned the same value, n*v can be entered where n = the number of repetitions of the value v.

(e.g., RNG = 0.5,1.0,2.5,3,5.5 assigns the five values to the five positions of the array RNG; DAY=2*0,1,50*0,1,314*0 assigns 0 to all positions in the array DAY except for positions 3 and 54, which are assigned a value of 1).

Discreet array positions can be assigned values by entering:

array (i) = v

where:

array = the name of the array

i = position within the array

v = value to be assigned to the array position i.

(e.g., DAY(3) = 1 will assign a value of 1 to position 3 of the array DAY).

After the last namelist card, the plant elevation and receptor elevation cards must be entered. The plant elevation card contains the elevation of the plant (feet above MSL) in columns 1-10. This card is not input if the value of IPTZ=0. If a value of IPTZ=1 was entered in the namelist cards, the plant elevation card must be input.

Thirty-six receptor elevation cards follow the plant elevation card, corresponding to the 36 azimuths located every 10 degrees, starting with 10° east of due north. Each receptor card contains the direction (tens of degrees) in columns 1-2, followed by five receptor elevations (ft MSL) corresponding to the five ring distances assigned to the namelist variable RNG. If the value of IPTZ=0, the receptor elevation cards must not be input. If a value of IPTZ=1 was entered in the namelist input, the receptor elevation cards must be input.

A delimiter card must be input following the last receptor elevation card. If no plant and receptor elevation cards were input (IPTZ=0) then the delimiter card must not be used.

After the receptor elevation delimiter card (if required), two cards must be input for each stack that is to be processed. Up to 19 stacks can be processed by the Single Source (CRSTER) Model. The first stack card is a stack identification card containing a descriptive name for the stack (e.g., Federal Power Commission number). The second stack card contains the emission rate (g s^{-1}), stack height (m), stack diameter (m), gas exit velocity (m s^{-1}) and stack temperature (°K). If the option for entering monthly values of emission rates (IQCK=1), exit velocity (IVCK=1) or temperature (ITCK=1) was specified in the namelist input, the corresponding field on each stack data card may be left blank. Table 4-10 contains a description of the format for each of the fixed format card types. Coding forms for preparing the data for keypunching are included in Appendix C.

b. Tape Input. A tape file of hourly meteorological data generated by the Preprocessor program (see Section 4.2.4) must be input to the Single Source (CRSTER) Model. The file should contain data for the most representative combination of surface and upper air stations. The NWS surface and upper air station numbers, and the year of record of the data on the tape must correspond to the values assigned to the namelist variables ISS, ISY, IUS, and IUY (see Section 4.3.3.a).

4.3.4 Output Data Description

The Single Source (CRSTER) Model generates printed output of the input data and modeling results, and an (optional) output file of hourly, daily and annual concentrations at each receptor point.

TABLE 4-10
SINGLE SOURCE (CRSTER) MODEL FIXED FORMAT INPUT CARD DESCRIPTIONS

	Contents		
Card Type	Card Columns	Format	Description
Heading Card	1-24	6A4	Plant Name
	25-32	2A4	Pollutant
Comment Card	1-80	20A4	Comments (first four columns must contain at least 1 non-blank character)
Comment Delimiter Card	1-80	80X	Blank
Plant Elevation Card	1-10	F10.4	Plant Elevation (ft MSL)
Receptor Elevation Card	1-2	I2	Direction (tens of degrees)
	3-10	8X	Blank
	11-20	F10.0	Receptor Elevation (ft MSL) for ring 1
	21-30	F10.0	Receptor Elevation (ft MSL) for ring 2
	31-40	F10.0	Receptor Elevation (ft MSL) for ring 3
	41-50	F10.0	Receptor Elevation (ft MSL) for ring 4
	51-60	F10.0	Receptor Elevation (ft MSL) for ring 5
Receptor Elevation Delimiter Card	1-80	80X	Blank
Stack Identification Card	1-80	20A4	Stack identification
Stack Data Card	1-10	F10.4	Emission Rate (gm/sec)
	11-20	10X	Blank
	21-30	F10.2	Stack Height (m)
	31-40	F10.2	Stack Diameter (m)
	41-50	F10.2	Stack gas exit velocity (m/sec)
	51-60	F10.2	Stack Temperature (°K)
Stack Delimiter Cards	1-80	80X	Blank

a. Printed Output. The printed output generated by the Single Source (CRSTER) Model can be classified into the following categories:

- Card input data listing
- Meteorological data listing
- Modeling results for a standard run
- Modeling results for a source contribution run

A card input data listing is generated by each Single Source (CRSTER) Model run. The card input data listing consists of a run identification page, a receptor data page, and one or more stack data pages.

The run identification page contains a listing of the comment cards and namelist options. Pages B-5 and B-29 (Appendix B) are examples of run identification pages. The first line on the page is a page heading printed on every page of output from the Single Source (CRSTER) Model. This is followed by the list of comment cards and a comparison of the upper air and surface meteorological data sources and year of record on the input tape with those specified in the namelist input; for example:

```
THIS IS A SINGLE SOURCE (CRSTER) MODEL EXAMPLE RUN.
THIS RUN ILLUSTRATES THE USE OF THE FOLLOWING OPTIONS:
*          SOURCE CONTRIBUTION
*          RUN FOR A SINGLE DAY
*          UNEVEN RECEPTOR TERRAIN
*          NO HOURLY OUTPUT TAPE
*          RURAL MIXING HEIGHTS
*          VARIABLE AVERAGING TIME
CINCINNATI SURFACE
DAYTON UPPER AIR

               MET FILE     REQUESTED
              STN NO. YR   STN I.D. YR
 SURFACE       93814  84     93814  84
 UPPER AIR     93815  84     93815  84
```

The program then prints options selected by the user in the namelist input, and the value assigned to each of the 366 positions in the DAY array that designates which days are to be modeled; for example:

```
PLANT LOCATION: RURAL
NO TAPE OUTPUT
Q VALUES REQUIRE MONTHLY INPUT
V VALUES REQUIRE MONTHLY INPUT
T VALUES REQUIRE MONTHLY INPUT

DAY== 0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
      0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
      0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 1 1 1 1 1 1   1 1 1 1 0 0 0 0 0 1   1 1 1 1 1 1 1 1 1 0
      0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
      0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
      0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
      0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
      0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0
```

The receptor data page tabulates the five receptor ring distances, the plant elevation, and the 180 receptor terrain elevations. Elevations are listed in both feet and meters. Pages B-6 and B-30 are examples of receptor data pages, and a partial listing of the format is shown below:

```
 RING DISTANCES(KM)=    .50   1.50   3.00   5.00   8.00

PLANT ELEVATION (FEET ABOVE SEA LEVEL)==     492.0        PLANT ELEVATION (METERS ABOVE SEA LEVEL)==     150.0

    RECEPTOR ELEVATIONS (FEET ABOVE SEA LEVEL)                RECEPTOR ELEVATIONS (METERS ABOVE SEA LEVEL)

DIRECTION    RING#1    RING#2    RING#3    RING#4    RING#5              RING#1    RING#2    RING#3    RING#4    RING#5

    1         540.0     500.0     470.0     510.0     460.0               164.6     152.4     143.3     155.5     140.2
    2         550.0     550.0     575.0     660.0     460.0               167.6     167.6     175.3     201.2     140.2
    3         525.0     615.0     625.0     710.0     460.0               160.0     187.5     190.5     216.4     140.2
    4         490.0     720.0     640.0     720.0     540.0               149.4     219.5     195.1     219.5     164.6

                                                     |
                                                     |
```

Information output on stack data pages consists of a stack identification list followed by an input stack data list. The format of the stack data list depends on whether or not monthly values were input for emission rate, exit velocity and/or temperature. If monthly values were input for any one of these parameters (i.e., IQCK=1, IVCK=1 or ITCK=1), twelve lines of print are generated for each stack, listing the monthly values. Pages B-7 and B-8 are examples of the monthly stack data, and a partial listing of this format is shown below:

```
STACK    MONTH      EMISSION RATE       HEIGHT    DIAMETER  EXIT VELOCITY   TEMP      VOLUMETRIC FLOW
                     (GMS/SEC)         (METERS)   (METERS)    (M/SEC)     (DEG,K)      (M**3/SEC)

  1       JAN         36.0000            83.00      3.05       19.40       420.00         141.74
          FEB         36.0000            83.00      3.05       19.40       420.00         141.74
          MAR         36.0000            83.00      3.05       19.40       420.00         141.74
          APR         36.0000            83.00      3.05       19.40       420.00         141.74
          MAY         36.0000            83.00      3.05       19.40       420.00         141.74
                                           |
```

If single, annual values for stack parameters are input instead, one line of print is generated for each stack as illustrated in the example on page B-31 and shown below:

```
STACK    MONTH      EMISSION RATE       HEIGHT    DIAMETER  EXIT VELOCITY   TEMP      VOLUMETRIC FLOW
                     (GMS/SEC)         (METERS)   (METERS)    (M/SEC)     (DEG,K)      (M**3/SEC)

  1       ALL         36.0000            83.00      3.05       19.40       420.00         141.74
```

Following the card input data listings, the Single Source (CRSTER) Model prints the hourly meteorological data for each day processed (i.e., each day corresponding to a position in the namelist array DAY that was assigned a value of 1). The listing of the hourly meteorology is composed of ten lines of print. The first line lists the year (yy), month (mm) and julian day (ddd) of record as follows:

JYR = yy IMO = mm JDAY = ddd

The next five lines list 24 values of stability class, wind speed (ms^{-1}), ambient temerature (°K), flow vector (degrees) and randomized flow vector (degrees), respectively. The last four lines of the hourly meteorology listing contain the hourly mixing height values (m) for rural (HLH1) and urban (HLH2) cases. Examples of the meteorological data listing are illustrated on pages B-8 through B-13 and shown below:

```
[illegible]
```

The Single Source (CRSTER) Model calculates pollutant concentrations for 1-hour, 3-hour, 24-hour, and annual* averaging periods. In addition, calculations are made for a variable averaging period (optional) which can be selected as 2, 4, 6, 8 or 12 hours by assigning a value to the IVT namelist variable (see Section 4.3.3.a). Modeling results printed out by a standard run of the Single Source (CRSTER) Model include the following:

- A listing of daily maximum 1-hour and 24-hour concentrations
- A table of the annual mean concentrations at each receptor
- A table for each averaging period, listing the highest concentration at each receptor and the maximum of these values
- A table for each averaging period (except the annual average), listing the second-highest concentration at each receptor point and the maximum of these values
- A table for each averaging time period (except the annual average) of the 50 highest concentrations for the entire year

The daily maximum 1-hour and 24-hour concentrations are listed for each day that is processed. If the meteorological data are being printed (i.e., MET=1), the maximum 1-hour and 24-hour concentration for each day are printed following the meteorology for that day, as follows:

```
                               M A X   H O U R L Y                                M A X   2 4 - H O U R
DAY      RATIO    CONCENTRATION  DIRECTION  DISTANCE(KM)  HOUR    CONCENTRATION  DIRECTION  DISTANCE(KM)
125     18.457     [illegible]      32          .50        12      [illegible]       8           3.00
```

---

*Note that all "annual average" concentrations output by the model represent averages taken over only those days for which the model was run. Thus, only if an entire year of data is processed will these be true annual averages.

The examples on pages B-8 through B-13 illustrate this format. If the meteorological data are not printed (i.e., MET=0), the heading for the daily maximum 1-hour and 24-hour concentrations is printed once on each page, followed by one line of print for each day. Up to 50 lines are printed on each page.

After the maximum 1-hour and 24-hour concentrations are printed for the last day processed, the table of annual mean concentrations is printed. Page B-14 is an example of the annual mean concentration table. The first line on this page (after the heading) lists the maximum annual concentration (g m^{-3}) at any receptor, and the direction (tens of degrees) and distance (km) of its location. This is followed by a table of annual mean concentrations (g m^{-3}) at each of the 180 receptor points. A partial listing of this format is given below:

```
        MAXIMUM MEAN CONC=  6.9179-05  DIRECTION=  4  DISTANCE=  3.8 KM


                     ANNUAL MEAN CONCENTRATION AT EACH RECEPTOR
     RANGE      .9 KM          1.5 KM          2.0 KM          3.8 KM          6.2 KM
DIR
 1            1.52284-06      5.78657-06      6.93891-06      1.13864-05      9.61568-06
 2            2.15679-05      1.32564-05      2.19758-05      3.59951-05      1.55926-05
 3            2.52828-06      2.51952-05      3.37759-05      5.66661-05      5.09605-05
 4            2.56767-06      5.97761-05      5.52931-05      6.91795-05      6.94937-05
 5            2.69925-06      8.16161-05      5.28855-05      1.79446-05      2.15586-05
                                                   :
                                                   :
                                                   :
```

The highest and second highest concentration tables have the same format for each averaging period. The first line after the page heading contains the yearly maximum highest or second-highest concentration (g m^{-3}) at any receptor; the receptor location (direction in tens of degrees, and distance in km) and time interval within the day* of the maximum. The table of highest (or second-highest) concentrations at each of the 180 receptors follows. This table contains 11 columns, one identifying the receptor azimuths and five pairs of columns, one for each of the five receptor ring distances. Each pair of columns contains one column of concentrations and one identifying the Julian day and associated time period. The Julian day and time period identifier are enclosed in parenthesis and separated by a comma. Table 4-11 is a list of time period identifiers for any given averaging period. Examples of highest and second-highest concentration tables for 24-hour, 8-hour, 3-hour and 1-hour averaging periods are given on pages B-15 through B-22. The basic format is summarized below:

---

*A time interval within the day is not listed for the 24-hour concentration tables since there is just one 24-hour period per day.

```
YEARLY MAXIMUM 24-HOUR CONC= [illegible]  DIRECTION= 4  DISTANCE= 5.0 KM  DAY=[illegible]

         HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR
 RANGE      .5 KM              1.0 KM              2.0 KM              3.5 KM              5.0 KM
DIR
 1   [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])
 2   [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])
 3   [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])
 4   [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])
 5   [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])
 6   [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])  [illegible] ([illegible])

                                          .
                                          .
                                          .
```

The fifty highest concentrations ranked in descending order are printed for each averaging period. Pages B-23 through B-26 are examples of tables of fifty highest concentrations for the 24-hour, 8-hour, 3-hour and 1-hour averaging periods, respectively. The tables list the Julian day number, concentration (gm^{-3}), receptor direction (tens of degrees) and distance (km), and time period identifier (see Table 4-11). A sample of the format is given below:

TABLE 4-11

TIME PERIOD IDENTIFIERS AND CORRESPONDING HOURS OF THE DAY (LOCAL STANDARD TIME)

Time Period Identifier #	Averaging Period 1-Hour	2-Hour	3-Hour	4-Hour	6-Hour	8-Hour	12-Hour
1	0-1	0-2	0-3	0-4	0-6	0-8	0-12
2	1-2	2-4	3-6	4-8	6-12	8-16	12-24
3	2-3	4-6	6-9	8-12	12-18	16-24	-
4	3-4	6-8	9-12	12-16	18-24	-	-
5	4-5	8-10	12-15	16-20	-	-	-
6	5-6	10-12	15-18	20-24	-	-	-
7	6-7	12-14	18-21	-	-	-	-
8	7-8	14-16	21-24	-	-	-	-
9	8-9	16-18	-	-	-	-	-
10	9-10	18-20	-	-	-	-	-
11	10-11	20-22	-	-	-	-	-
12	11-12	22-24	-	-	-	-	-
13	12-13	-	-	-	-	-	-
14	13-14	-	-	-	-	-	-
15	14-15	-	-	-	-	-	-
16	15-16	-	-	-	-	-	-
17	16-17	-	-	-	-	-	-
18	17-18	-	-	-	-	-	-
19	18-19	-	-	-	-	-	-
20	19-20	-	-	-	-	-	-
21	20-21	-	-	-	-	-	-
22	21-22	-	-	-	-	-	-
23	22-23	-	-	-	-	-	-
24	23-24	-	-	-	-	-	-

```
               MAXIMUM DAILY CONCENTRATIONS
    DAY    24-HOUR CONCENTRATION    DIRECTION    DISTANCE

    129          2.4790-05              5          3.00
    143          2.3060-05              7          6.20
    146          2.0390-05              6          1.50
    151          1.9010-05             20          2.20
    126          1.8567-05              7          3.40
    137          1.8640-05              3          3.00
    130          1.8959-05              7          6.20
    120          1.7147-05              4          3.40
    148          1.6083-05             11          1.50
    131          1.6097-05             10          3.00
    135          1.5318-05              7          6.00
    136          1.4206-05             20          2.00
    125          1.3145-05              8          3.00
    141          1.2828-05              4          3.00
    140          1.2135-05             13          3.00
    143          9.8304-06              6          2.00
    147          9.1005-06              3          3.00
    138          8.6755-06             20          2.20
    133          8.5918-06              7          2.20
    144          8.5766-06             21          2.20
```

⋮

A source contribution run of the Single Source (CRSTER) Model generates a source contribution table for each day processed. The source contribution table is printed after the meteorological data for that day. If several days are run, the source contribution tables and meteorological data are interspersed. If the meteorological data output was suppressed for the run (IMET=0), only the source contribution tables are printed. The source contribution tables list individual stack contributions to the total concentration at selected receptor points for each averaging time period. Different receptor points can be specified for each averaging period, and source contribution listings will be output for <u>only</u> those averaging periods for which receptor points have been input. The receptor points are specified in the namelist arrays SC1, SC3, SCV, SC24 and SCAN (see Section 4.3.3.a). The concentrations for each time period within the day are printed in the order that they are calculated, and so at first glance the output as shown in Table 4-12 may be confusing. One line is printed for each combination of receptor, averaging period, and time period identifier. The data printed on each line are the averaging period (INT), the julian day number (DAY), the time period identifier (PER), the receptor identification (R/DR, i.e., ring number/direction), ten stack concentrations (gm^{-3}) and the total concentration. If more than ten stacks were modeled, a second line is printed containing the remaining stack concentrations. Pages B-32 through B-34 illustrate a source contribution table for a single day using four receptor points for each standard averaging period and a variable averaging period of 8 hours.

TABLE 4-12

SOURCE CONTRIBUTION TABLE OUTPUT BY THE SINGLE SOURCE (CRSTER) MODEL

PLANT NAME: EXAMPLE RUN   POLLUTANT: SO2   EMISSION UNITS: GM/SEC   AIR QUALITY UNITS: GM/M**3

SOURCE CONTRIBUTION TABLE   NO. OF SOURCES: 4

[illegible]	DAY	[illegible]	[illegible]	SOURCE 1	SOURCE 2	SOURCE 3	SOURCE 4	SOURCE 5	SOURCE 6	SOURCE 7	SOURCE 8	SOURCE 9	SOURCE 10	TOTAL
1	2	1	1/ 1	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	1	1/ 2	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	1	1/ 3	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	1	1/ 4	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	2	1/ 1	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	2	1/ 2	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	2	1/ 3	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	2	1/ 4	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	3	1/ 1	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	3	1/ 2	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	3	1/ 3	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	3	1/ 4	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
3	2	1	2/ 1	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
3	2	1	2/ 2	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
3	2	1	2/ 3	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
3	2	1	2/ 4	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	4	1/ 1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	4	1/ 2	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	4	1/ 3	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	4	1/ 4	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	5	1/ 1	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	5	1/ 2	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	5	1/ 3	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	5	1/ 4	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	6	1/ 1	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	6	1/ 2	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	6	1/ 3	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	6	1/ 4	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
3	2	2	2/ 1	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
3	2	2	2/ 2	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
3	2	2	2/ 3	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
3	2	2	2/ 4	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	7	1/ 1	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	7	1/ 2	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	7	1/ 3	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	7	1/ 4	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	8	1/ 1	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	8	1/ 2	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	8	1/ 3	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	8	1/ 4	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
0	2	1	3/ 1	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
0	2	1	3/ 2	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
0	2	1	3/ 3	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
0	2	1	3/ 4	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	9	1/ 1	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	9	1/ 2	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	9	1/ 3	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
1	2	9	1/ 4	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
3	2	3	2/ 1	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]
3	2	3	2/ 2	[illegible]	[illegible]	[illegible]	[illegible]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	[illegible]

b. Tape Output. An output tape can be generated by a standard run of the Single Source (CRSTER) Model containing hourly, daily and annual concentrations for each receptor point. The tape is generated if a value of 1 is assigned to the namelist variable ITAP (see Section 4.3.3.a). Each record on the file contains 180 concentration values written with a FORTRAN unformatted WRITE statement. The 180 values correspond to the concentrations along each of the 36 azimuths, at each ring distance as follows:

- Values 1-36 correspond to Ring 1, directions 1-36
- Values 37-72 correspond to Ring 2, directions 1-36
- Values 73-108 correspond to Ring 3, directions 1-36
- Values 109-144 correspond to Ring 4, directions 1-36
- Values 145-180 correspond to Ring 5, directions 1-36

The records are arranged in the file as follows:

- 1-hour concentrations for Hour 1 of Day 1
- 1-hour concentrations for Hour 2 of Day 1

⋮

- 1-hour concentrations for Hour 24 of Day 1
- 24-hour concentrations for Day 1
- 1-hour concentrations for Hour 1 of Day 2

⋮

- 1-hour concentrations for Hour 24 of Day 2
- 24-hour concentrations for Day 2

⋮

- 1-hour concentrations for Hour 1 of Day N

⋮

- 1-hour concentrations for Hour 24 of Day N
- 24-hour concentrations for Day N
- "Annual mean" concentrations

where N is the number of the last day processed.

Records are output only for days corresponding to positions in the namelist array DAY that were assigned a value of 1 (see Section 4.3.3.a). The "annual mean" concentrations on the last record are averages based only on data from these days, i.e., are not true annual averages unless the entire year is processed. The record of annual mean concentrations is not output for source contribution runs.

4.3.5 Diagnostic Messages

Three types of diagnostic messages may be generated by the Single Source (CRSTER) Model, namely, fatal error messages, non-fatal error messages and informative messages.

Fatal error messages are printed when an error is detected that causes the program to stop execution. This is normally due to an error with some input data. Table 4-13 is a list of the possible fatal error messages and the corrective action that should be taken.

Non-fatal error messages are printed when a data item does not conform with input specifications, but the program makes an assumption or uses default values, allowing execution to continue. Table 4-14 is a list of the non-fatal error messages that may be output by the Single Source (CRSTER) Model. If a non-fatal error message is printed, the user must determine if the assumptions made by the Single Source (CRSTER) Model were acceptable. If not, the input data item in question should be corrected and the model rerun.

Informative messages are printed when the user has selected an option that differs from the default. Table 4-15 is a list of the informative messages that may be generated by the Single Source (CRSTER) Model. No user action is required in response to an informative message.

Lastly, Table 4-16 is a Julian day to calendar day conversion chart. Users who experience significant problems in executing the Single Source (CRSTER) Model may receive technical assistance by telephoning the Chief, Modeling Support Section, Source Receptor Analysis Branch in Durham, NC at 919-541-5335 or, using FTS, 629-5335

TABLE 4-13

SINGLE SOURCE (CRSTER) MODEL FATAL ERROR MESSAGES

```
BAD RECEPTOR REQUESTED FOR SOURCE CONTRIBUTION -- END RUN
```

Description: The source contribution option was requested (ISC = 1), but a value was entered for a distance in one of the SC1, SC3, SCN, SC24 or SCAN arrays that did not correspond to any of the five distances in the RNG array.

Action: Check all input distances and correct any that are incorrect.

```
NO MATCH FOR SURFACE/UPPER AIR REQUEST
              MET FILE          REQUESTED
           STN NO.   YR      STN NO.   YR

SURFACE      issf    isyf       iss    isy
UPPER AIR    iusf    iuyf       ius    iuy
```

Description: The requested surface station number (namelist item ISS with value iss) or year (namelist item ISY with value isy) or upper air station number (namelist item IUS with value ius) or year (namelist item IUY with value iuy) did not match the corresponding value on the input meteorological data tape (values issf, isyf, iusf and iuyf, respectively).

Action: Correct any namelist items that did not match the values on the tape, or check to be sure that the correct meteorological data file was specified in the ECL.

```
INVALID IUR:  iur, ABORT RUN
```

Description: The value iur was input for namelist item IUR. Only the values 1 (for rural) or 2 (for urban) can be used.

Action: Enter the correct value for IUR.

TABLE 4-13 (Continued)

SINGLE SOURCE (CRSTER) MODEL FATAL ERROR MESSAGES

```
*** MAXIMUM OF 19 STACKS EXCEEDED --- RUN TERMINATED
```

Description: Data for more than 19 stacks were entered.

Action: Reduce the number of stacks by combining similar stacks, if possible.

```
*** RECEPTOR HEIGHT GREATER THAN HEIGHT OF LOWEST STACK - RUN TERMINATED
```

Description: Receptor elevations cannot exceed the elevation of the top of the lowest stack (stack height plus the terrain elevation at the source).

Action: Change any receptor elevations that exceed the height of the lowest stack to be equal to that value, and rerun.

TABLE 4-14

SINGLE SOURCE (CRSTER) MODEL NON-FATAL ERROR MESSAGES

INVALID ITAP VALUE: n, SET TO 0

Description: The namelist item ITAP can only be assigned a value of 0 to 1. The value entered (n) was invalid. The Single Source Model assumes a value of 0 (no tape output) and continues execution.

INVALID IPTZ VALUE: n, SET TO 0

Description: The namelist item IPTZ can only be assigned a value of 0 or 1. The value entered (n) was invalid. The Single Source Model assumes a value of 0 (flat terrain) and continues execution.

INVALID IVT VALUE: n, SET TO 0

Description: The namelist item IVT can only be assigned a value of 0,2,4,6,8 or 12. The value entered (n) was invalid. The Single Source Model assumes a value of 0 (no variable averaging time period) and continues execution.

RECEPTOR ELEVATION LESS THAN PLANT ELEVATION — RECEPTOR ELEVATION SET TO PLANT ELEVATION n TIMES

Description: Single Source Model automatically sets the terrain elevation for a receptor equal to the plant elevation if the terrain at a receptor was lower than the plant terrain. The value n is the number of receptor points with terrain lower than the plant terrain elevation.

TABLE 4-15

SINGLE SOURCE (CRSTER) MODEL INFORMATIVE MESSAGES

Q VALUES REQUIRE MONTHLY INPUT

Description: A value of 1 was entered for namelist item IQCK, specifying that monthly emission rates are to be used. The namelist array QSSN should have been assigned 12 emission rate values to each stack.

V VALUES REQUIRE MONTHLY INPUT

Description: A value of 1 was entered for namelist item IVCK, specifying that monthly stack gas exit velocity values are to be used. The namelist array VSSN should have been assigned 12 exit velocity values for each stack.

T VALUES REQUIRE MONTHLY INPUT

Description: A value of 1 was entered for namelist item ITCK, specifying that monthly stack gas exit temperatures are to be used. The namelist array TSSN should have been assigned 12 values for each stack.

MET DATA WILL NOT BE PRINTED

Description: A value of 0 was entered for namelist item IMET specifying that the hourly meteorological data for each day is not to be printed.

TABLE 4-15 (Continued)

SINGLE SOURCE (CRSTER) MODEL INFORMATIVE MESSAGES

N GREATER THAN 45
X = x, YD = Δ_y, H = h, TOT = t, SUM = s

Description: This message is printed when the number of iterations in calculating multiple eddy reflections exceeds 45. The value x is the ring distance (m) at which the calculation is made, Δ_y is the crosswind distance (m) of the receptor from the plume center line, h is the effective height (m) of the stack adjusted for terrain, t is the current eddy reflection calculation, and s is the sum of all eddy reflection calculations. No further iterations are made, and the current value of s is used to calculate the concentration.

DAY -- n NO CALCULATIONS PERFORMED - NO DIRECTIONS SELECTED

Description: This message is printed only when no calculations are made for an entire 24 hour period. This condition can only occur if the atmospheric stability class on the tape for the entire day was stability class 7.

TABLE 4-16

JULIAN DAY TO CALENDAR DAY CONVERSION CHART FOR LEAP YEARS*

JAN		FEB		MAR		APR		MAY		JUN		JUL		AUG		SEP		OCT		NOV		DEC	
1	1	1	32	1	61	1	92	1	122	1	153	1	183	1	214	1	245	1	275	1	306	1	336
2	2	2	33	2	62	2	93	2	123	2	154	2	184	2	215	2	246	2	276	2	307	2	337
3	3	3	34	3	63	3	94	3	124	3	155	3	185	3	216	3	247	3	277	3	308	3	338
4	4	4	35	4	64	4	95	4	125	4	156	4	186	4	217	4	248	4	278	4	309	4	339
5	5	5	36	5	65	5	96	5	126	5	157	5	187	5	218	5	249	5	279	5	310	5	340
6	6	6	37	6	66	6	97	6	127	6	158	6	188	6	219	6	250	6	280	6	311	6	341
7	7	7	38	7	67	7	98	7	128	7	159	7	189	7	220	7	251	7	281	7	312	7	342
8	8	8	39	8	68	8	99	8	129	8	160	8	190	8	221	8	252	8	282	8	313	8	343
9	9	9	40	9	69	9	100	9	130	9	161	9	191	9	222	9	253	9	283	9	314	9	344
10	10	10	41	10	70	10	101	10	131	10	162	10	192	10	223	10	254	10	284	10	315	10	345
11	11	11	42	11	71	11	102	11	132	11	163	11	193	11	224	11	255	11	285	11	316	11	346
12	12	12	43	12	72	12	103	12	133	12	164	12	194	12	225	12	256	12	286	12	317	12	347
13	13	13	44	13	73	13	104	13	134	13	165	13	195	13	226	13	257	13	287	13	318	13	348
14	14	14	45	14	74	14	105	14	135	14	166	14	196	14	227	14	258	14	288	14	319	14	349
15	15	15	46	15	75	15	106	15	136	15	167	15	197	15	228	15	259	15	289	15	320	15	350
16	16	16	47	16	76	16	107	16	137	16	168	16	198	16	229	16	260	16	290	16	321	16	351
17	17	17	48	17	77	17	108	17	138	17	169	17	199	17	230	17	261	17	291	17	322	17	352
18	18	18	49	18	78	18	109	18	139	18	170	18	200	18	231	18	262	18	292	18	323	18	353
19	19	19	50	19	79	19	110	19	140	19	171	19	201	19	232	19	263	19	293	19	324	19	354
20	20	20	51	20	80	20	111	20	141	20	172	20	202	20	233	20	264	20	294	20	325	20	355
21	21	21	52	21	81	21	112	21	142	21	173	21	203	21	234	21	265	21	295	21	326	21	356
22	22	22	53	22	82	22	113	22	143	22	174	22	204	22	235	22	266	22	296	22	327	22	357
23	23	23	54	23	83	23	114	23	144	23	175	23	205	23	236	23	267	23	297	23	328	23	358
24	24	24	55	24	84	24	115	24	145	24	176	24	206	24	237	24	268	24	298	24	329	24	359
25	25	25	56	25	85	25	116	25	146	25	177	25	207	25	238	25	269	25	299	25	330	25	360
26	26	26	57	26	86	26	117	26	147	26	178	26	208	26	239	26	270	26	300	26	331	26	361
27	27	27	58	27	87	27	118	27	148	27	179	27	209	27	240	27	271	27	301	27	332	27	362
28	28	28	59	28	88	28	119	28	149	28	180	28	210	28	241	28	272	28	302	28	333	28	363
29	29	29	60	29	89	29	120	29	150	29	181	29	211	29	242	29	273	29	303	29	334	29	364
30	30			30	90	30	121	30	151	30	182	30	212	30	243	30	274	30	304	30	335	30	365
31	31			31	91			31	152			31	213	31	244			31	305			31	366

*For non-leap years, subtract 1 from Julian Day numbers corresponding to calendar days after February 28.

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APPENDIX A
PROGRAM SOURCE LISTINGS

Listings of the FORTRAN source code for the Preprocessor and Single Source (CRSTER) Model are contained in this section. The various program elements begin or the following pages:

Program Element	Page Number
Preprocessor Programs	A-3
Single Source (CRSTER) Model	
Main Program	A-11
Subroutine CRS	A-18
Subroutine SIGMA	A-44
Subroutine BEHO72	A-49
Block Data	A-53

PREPROCESSOR PROGRAM

```
C***CRSTER-PREPROCESSOR- WRITTEN BY JOAN HRENKO NOVAK                   MET00010
C*** BASED ON METHODS SUGGESTED BY TURNER , ZIMMERMAN, AND IRWIN.       MET00020
C*** VERSION 77166                                                      MET00030
C***THE PROGRAM ASSUMES THERE IS NO MISSING DATA ON THE MET. TAPE.      MET00040
C***IF MISSING DATA IS DETECTED, THE LOCATION OF THE MISSING DATA IS    MET00050
C***PRINTED. MISSING DATA MUST BE FILLED IN BEFORE PROCESSING .         MET00060
      DIMENSION LSTAB(12,7), IDFAC(12,2), ANGL(3), ICEIL(3), IDG(3), IDIMET00070
     1G(11)                                                             MET00080
      DIMENSION WST(24), SPEED(24), TEMP(24), AFV(24), FVR(24), HLH(2,24MET00090
     1), RAND(24)                                                       MET00100
      DATA IDIG /'0','1','2','3','4','5','6','7','8','9','-'/           MET00110
      DATA IREC /1/ ,IHD /1/ ,ANGL /60.,35.,15./ ,CONST /57.29578/      MET00120
      DATA IDFAC /0,31,59,90,120,151,181,212,243,273,304,334,0,31,60,91,MET00130
     1121,152,182,213,244,274,305,335/                                  MET00140
      DATA LSTAB /7,7,7,6,6,6,6,5,5,5,5,4,4,4,4,4,4,5,5,5,4,4,4,4,4,4,4,MET00150
     24,4,4,4,4,4,4,4,4,3,3,3,4,4,4,4,4,4,4,4,4,4,2,2,2,3,3,3,3,3,4,4,4,4,MET00160
     21,2,2,2,2,2,2,3,3,3,3,4,1,1,1,1,1,2,2,2,2,3,3,3/                  MET00170
C***   UNIT 8 = SURFACE DATA                                            MET00180
C***   UNIT 9 = OUTPUT FILE                                             MET00190
C***   UNIT 5 = UPPER AIR DATA IN CARD FORMAT                           MET00200
      IN=5                                                              MET00210
      IO=6                                                              MET00220
      IFLAG=0                                                           MET00230
C***READ CARD TO INITIALIZE MET TAPE ID,YEAR,LATITUDE,LONGITUDE,        MET00240
C*** TIME ZONE ,NO. OF DAYS IN YEAR, INITIAL RANDOM NUMBER.             MET00250
C***RAND(24) IS THE INITIAL RANDOM NO. USED TO GENERATE THE SEQUENCE OF MET00260
C***NUMBERS FOR THE RANDOMIZED FLOW VECTOR. IF THE SAME NO. IS USED IN  MET00270
C***DIFFERENT EXECUTIONS OF THE PREPROCESSOR, THE SAME SET OF RANDOM NOSMET00280
C***WILL BE GENERATED. ANY ODD NUMBER GREATER THAN 3 DIGITS CAN BE USED MET00290
C***AS THE SEED. THIS SEED IS MULTIPLIED BY 10000 INTERNALLY.           MET00300
C***ZONE IS GMT-LST.                                                    MET00310
      READ (IN,400) IDC,IYRC,ALAT,ALNG,ZONE,NDAYS,RAND(24)              MET00320
      WRITE (IO,410) IDC,IYRC,ALAT,ALNG,ZONE,NDAYS,RAND(24)             MET00330
      DUM=ALAT/CONST                                                    MET00340
      SINLAT=SIN(DUM)                                                   MET00350
      COSLAT=COS(DUM)                                                   MET00360
      DUM=ALNG/15.-ZONE                                                 MET00370
      TEMPZ=15.*ZONE-ALNG                                               MET00380
C***RESET SUBSCRIPT IF LEAP YEAR                                        MET00390
      LYS=1                                                             MET00400
```

```
                                                                        MET00410
      IF (NDAYS.EQ.366) LYS=2                                           MET00420
C***READ MET DATA                                                       MET00430
C***THIS READ ASSUMES AN INPUT TAPE WITH HOURLY DATA FROM THE           MET00440
C***NATIONAL CLIMATIC CENTER, ASHEVILLE, NC. IN THEIR STANDARD          MET00450
C***HOURLY CARD FORMAT.                                                 MET00460
C***SKIP 00 HOUR OF MET DATA.                                           MET00470
      READ (8,420) ID,IYEAR,IMONTH,IDAY,IHOUR,ICEIL,IDIR,ISPEED,ITEMP,ICMET00480
     1OVER                                                              MET00490
      LWD=IDIR                                                          MET00500
C***BEGIN PROCESSING WITH HOUR 01                                       MET00510
      READ (8,420) ID,IYEAR,IMONTH,IDAY,IHOUR,ICEIL,IDIR,ISPEED,ITEMP,ICMET00520
     1OVER                                                              MET00530
C***MIXING HEIGHT VALUES ARE DETERMINED TWICE A DAY FROM RADIOSONDE DATAMET00540
C***USING THE PROCEDURES OF HOLZWORTH.                                  MET00550
C***READ PRIOR DAYS MIXING HEIGHT VALUES                                MET00560
      READ (3,430) XMAM1,XMPM1                                          MET00570
C***PRESENT DAY                                                         MET00580
      READ (3,440) IDM,IYM,XMAM,XMPM                                    MET00590
C***WRITE IDENTIFYING INFORMATION ON OUTPUT FILE                        MET00600
      WRITE (9) ID,IYEAR,IDM,IYM                                        MET00610
      WRITE (10,450) IYEAR,ID,IYM,IDM                                   MET00620
C*** READ NEXT DAY'S MIXING HEIGHT VALUES                               MET00630
      READ (3,430) XMAP1,XMPP1                                          MET00640
C***START DAY LOOP.                                                     MET00650
      DO 380 IDY=1,NDAYS                                                MET00660
C***CALCULATE THE DAY NO AND THE TIME OF SUNRISE AND SUNSET             MET00670
      DAY1=IDAY+IDFAC(IMONTH,LYS)                                       MET00680
C***CONSTANT 0.0172028=360./365.242*57.29578                            MET00690
C***DETERMINE THE ANGULAR(RADIANS) FRACTION OF A YEAR FOR THIS DATE.    MET00700
      DAYNO=(DAY1-1.0)*0.0172028                                        MET00710
      TDAYNO=2.*DAYNO                                                   MET00720
      SIND=SIN(DAYNO)                                                   MET00730
      COSD=COS(DAYNO)                                                   MET00740
      SINTD=SIN(TDAYNO)                                                 MET00750
      COSTD=COS(TDAYNO)                                                 MET00760
C***ACCOUNT FOR ELLIPTICITY OF EARTH'S ORBIT.                           MET00770
      SIGMA=279.9348+(DAYNO*CONST)+1.914827*SIND-0.079525*COSD+0.019938*MET00780
     1SINTD-0.00162*COSTD                                               MET00790
C***CONSTANT 0.39785=SIN(.4091720193=23.44*360/57.29578)                MET00800
C***FIND THE SINE OF THE SOLAR DECLINATION.
```

```
      DSIN=0.39785*SIN(SIGMA/CONST)                                     MET00810
      DCOS=SQRT(1.0-DSIN*DSIN)                                          MET00820
C***DETERMINE TIME(HRS) OF MERIDIAN PASSAGE                             MET00830
      AMM=12.0+0.12357*SIN(D)-0.004289*COS(D)+0.153809*SIN(TD)+0.060783*COS(TD) MET00840
      HCOS=(-SIN(LAT)*DSIN)/(COS(LAT)*DCOS)                             MET00850
C***DETERMINE SOLAR HOUR ANGLE OF SUNRISE-SUNSET.                       MET00860
      H2=(ATAN2(SQRT(1.-HCOS*HCOS),HCOS)/15.0)*CONST                    MET00870
C***TIME OF SUNRISE(TSR) AND TIME OF SUNSET(TSS) ARE EXPRESSED IN       MET00880
C***LOCAL STANDARD TIME SINCE THE ZONE CORRECTION HAS ALREADY BEEN MADE.MET00890
C***OTHERWISE THEY WOULD BE IN GREENWICH MEAN TIME.                     MET00900
      TSR=AMM-H2-DLM                                                    MET00910
      TSS=AMM+H2-DLM                                                    MET00920
      RAND(1)=RAND(24)*10000.                                           MET00930
C***THIS CALL TO THE UNIVAC RANDOM NO. GENERATOR PROVIDES 24 UNIFORMLY  MET00940
C***DISTRIBUTED NUMBERS BETWEEN 0 AND 1.                                MET00950
C***IF THIS ROUTINE IS NOT RUN ON A UNIVAC MACHINE, THE RANDOM NO.      MET00960
C***GENERATOR FOR THE USER'S SYSTEM MAY BE SUBSTITUTED.                 MET00970
      CALL RANDU (RAND,24)                                              MET00980
C***START HOUR LOOP                                                     MET00990
      DO 370 KHR=1,24                                                   MET01000
      KHRC=KHR                                                          MET01010
C***INITIALIZE STABILITY BEFORE IT IS CALCULATED                        MET01020
      KST(KHR)=0                                                        MET01030
      IF (KHR.EQ.24) GO TO 70                                           MET01040
C***CHECK DATA FOR CORRECTNESS & CONTINUITY                             MET01050
C***CHECK STATION NUMBER.                                               MET01060
      IF (ID.EQ.IDC) GO TO 10                                           MET01070
      WRITE (IO,460) IREC,ID,IDC                                        MET01080
      WRITE (IO,510)                                                    MET01090
      CALL EXIT                                                         MET01100
C***CHECK YEAR.                                                         MET01110
10    IF (IYEAR.EQ.IYRC) GO TO 20                                       MET01120
      WRITE (IO,470) IYEAR,IYRC,IREC                                    MET01130
      WRITE (IO,510)                                                    MET01140
      CALL EXIT                                                         MET01150
C***CHECK MONTH                                                         MET01160
20    IF (IMONTH.EQ.IMO) GO TO 40                                       MET01170
      IF (IMONTH.EQ.(IMO+1)) GO TO 30                                   MET01180
      WRITE (IO,480) IMONTH,IMO,IREC                                    MET01190
C***                                                                    MET01200
```

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      WRITE (IO,510)                                                    MET01210
      CALL EXIT                                                         MET01220
30    IMO=IMONTH                                                        MET01230
C***CHECK DAY                                                           MET01240
40    IF (IFIX(DAY1).EQ.IDY) GO TO 50                                   MET01250
      WRITE (IO,490) DAY1,IDY,IREC                                      MET01260
      WRITE (IO,510)                                                    MET01270
      CALL EXIT                                                         MET01280
C***CHECK HOUR                                                          MET01290
50    IF (IHOUR.EQ.KHRC) GO TO 70                                       MET01300
      WRITE (IO,500) IHOUR,KHR,IREC                                     MET01310
      WRITE (IO,510)                                                    MET01320
      GO TO 370                                                         MET01330
60    WRITE (IO,520) KHR,IREC,IHOUR                                     MET01340
      CALL EXIT                                                         MET01350
70    IF (IHOUR.NE.1) GO TO 80                                          MET01360
      KHRC=IHOUR                                                        MET01370
C***UPDATE MIXING HEIGHTS- STARTING NEW DAY.                            MET01380
      XMAMO=XMA                                                         MET01390
      XAFMO=XAF                                                         MET01400
      XMA=XMAP1                                                         MET01410
      XAF=XAFP1                                                         MET01420
C***READ NEXT DAYS MIXING HEIGHTS.                                      MET01430
      READ (IM,430,END=80) XMAP1,XAFP1                                  MET01440
80    DO 90 JK=1,11                                                     MET01450
      IF (ICOVER.EQ.IDDG(JK)) GO TO 100                                 MET01460
90    CONTINUE                                                          MET01470
      JK=11                                                             MET01480
      WRITE (IO,530) ICOVER                                             MET01490
100   ISKY=JK-1                                                         MET01500
      IF (ICEIL(1).NE.IDDG(11)) GO TO 110                               MET01510
      IDG(1)=9                                                          MET01520
      IDG(2)=9                                                          MET01530
      IDG(3)=9                                                          MET01540
      GO TO 150                                                         MET01550
110   DO 140 JD=1,3                                                     MET01560
      DO 120 JK=1,10                                                    MET01570
      IF (ICEIL(JD).EQ.IDDG(JK)) GO TO 130                              MET01580
120   CONTINUE                                                          MET01590
130   IDG(JD)=JK-1                                                      MET01600
```

```
140   CONTINUE                                                        MET01610
150   IROOF=IDG(1)*100+IDG(2)*10+IDG(3)                               MET01620
C***IROOF IS CEILING HEIGHT IN HUNDREDS OF FEET.                      MET01630
C***CONVERT TEMP FROM FAHRENHEIT TO KELVIN                            MET01640
      TEMP(KHR)=0.5556*(ITEMP-32.)+273.15                             MET01650
C***CONVERT WIND SPEED FROM KNOTS TO METERS/SEC                       MET01660
      S=ISPEED*0.5144                                                 MET01670
C***WIND SPEED IS SET TO 1 METER/SEC                                  MET01680
      IF (S.LT.1.0) S=1.0                                             MET01690
      SPEED(KHR)=S                                                    MET01700
C***CHECK FOR CALMS                                                   MET01710
      IF (IDIR.EQ.0) GO TO 160                                        MET01720
C***WIND DIRECTION IS ASSUMED TO BE THE SAME AS FOR THE LAST HOUR     MET01730
C***IF THE WIND DIRECTION IS REPORTED AS "CALM".                      MET01740
      LWD=IDIR                                                        MET01750
      GO TO 170                                                       MET01760
160   IDIR=LWD                                                        MET01770
170   XDIR=IDIR*10.                                                   MET01780
C***CALCULATE FLOW VECTOR AND RANDOM FLOW VECTOR                      MET01790
      IF (XDIR.GT.180.) GO TO 180                                     MET01800
      FV=XDIR+180.                                                    MET01810
      GO TO 190                                                       MET01820
180   FV=XDIR-180.                                                    MET01830
190   AFV(KHR)=FV                                                     MET01840
      IRAND=RAND(KHR)*10.                                             MET01850
C***IRAND IS SINGLE DIGIT FROM 0 TO 9.                                MET01860
      FVR(KHR)=FV+IRAND-4.0                                           MET01870
      IF (FVR(KHR).GT.360.) FVR(KHR)=FVR(KHR)-360.                    MET01880
C***DETERMINE RADIATION INDEX.                                        MET01890
      IF (ISKY.EQ.10.AND.IROOF.LT.70) GO TO 200                       MET01900
      IF (IHOUR.GT.TSR.AND.IHOUR.LT.TSS) GO TO 210                    MET01910
      IRADN=2                                                         MET01920
      IF (ISKY.LE.4) IRADN=1                                          MET01930
      GO TO 280                                                       MET01940
200   IRADN=3                                                         MET01950
      GO TO 280                                                       MET01960
C***DETERMINE THE ANGLE OF ELEVATION                                  MET01970
C***DETERMINE SOLAR HOUR ANGLE(RADIANS)                               MET01980
210   HI=(15.*(KHRC-6HR)-TEMPZ)/CONST                                 MET01990
      ALFSN=SINLAT*DSIN+DCOS*COSLAT*COS(HI)                           MET02000
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C***DETERMINE SOLAR ELEVATION ANGLE(DEG).                               MET02010
      ALF=ATAN2(ALFSN,SQRT(1.-ALFSN*ALFSN))*CONST                       MET02020
      DO 220 I=1,3                                                      MET02030
220   IF (ALF.GT.ANGL(I)) GO TO 230                                     MET02040
      I=4                                                               MET02050
230   ICN=5-I                                                           MET02060
      IF (ISKY.GT.5) GO TO 240                                          MET02070
      IRADX=ICN+3                                                       MET02080
      GO TO 280                                                         MET02090
240   IRADX=ICN-1                                                       MET02100
      IF (IROOF.LT.70) GO TO 250                                        MET02110
      IF (IROOF.LT.160) GO TO 260                                       MET02120
      IF (ISKY.EQ.10) GO TO 270                                         MET02130
      IRADX=ICN                                                         MET02140
      GO TO 270                                                         MET02150
250   IRADX=ICN-2                                                       MET02160
      GO TO 270                                                         MET02170
260   IF (ISKY.EQ.10) IRADX=IRADX-1                                     MET02180
270   IF (IRADX.LT.1) IRADX=1                                           MET02190
      IRADX=IRADX+3                                                     MET02200
280   IND=ISPEED                                                        MET02210
      IF (ISPEED.GT.12) IND=12                                          MET02220
      IF (ISPEED.LE.1) IND=1                                            MET02230
C***DETERMINE STABILITY.                                                MET02240
      KST(KHR)=LSTAB(IND,IRADX)                                         MET02250
C***DO NOT ALLOW STABILITY TO VARY RAPIDLY                              MET02260
      IF (IDY.EQ.1.AND.KHR.EQ.1) LST=KST(KHR)                           MET02270
      IF ((KST(KHR)-LST).GT.1) KST(KHR)=LST+1                           MET02280
      IF ((LST-KST(KHR)).GT.1) KST(KHR)=LST-1                           MET02290
      LST=KST(KHR)                                                      MET02300
      IF (KST(KHR).LT.1) WRITE (IO,540) KST(KHR),IND,IRADX,IREC         MET02310
C***CALCULATE MIXING HEIGHT                                             MET02320
      IHR=KHRC                                                          MET02330
      XHR=IHR                                                           MET02340
      IF (IHR.GT.14.AND.XHR.LE.TSS) GO TO 300                           MET02350
      IND=2                                                             MET02360
      IF (XHR.LE.TSS) GO TO 310                                         MET02370
      IF (KST(KHR).EQ.4) GO TO 290                                      MET02380
      HLH(2,KHR)=XMF+(XMXPS-XMF)*((XHR-TSS)/(24.-TSS))                  MET02390
      IND=1                                                             MET02400
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```
290   HLH(IND,KHR)=XAF+(XAFP1-XAF)*((KHR-TSS)/(36.-TSS))                MET02410
      IF (IND.EQ.2) HLH(1,KHR)=HLH(2,KHR)                                MET02420
      GO TO 360                                                          MET02430
300   HLH(1,KHR)=XAF                                                     MET02440
      HLH(2,KHR)=XAF                                                     MET02450
      GO TO 360                                                          MET02460
310   IF (KHR.GT.TSR) GO TO 330                                          MET02470
      KSTSP=KST(KHR)                                                     MET02480
      IF (KST(KHR).EQ.4) GO TO 320                                       MET02490
      HLH(2,KHR)=XMN                                                     MET02500
      IND=1                                                              MET02510
320   HLH(IND,KHR)=XAFM1+(XAF-XAFM1)*((24.-TSS+KHR)/(24.-TSS+24.))       MET02520
      IF (IND.EQ.2) HLH(1,KHR)=HLH(2,KHR)                                MET02530
      GO TO 360                                                          MET02540
330   IF (KSTSP.EQ.4) GO TO 350                                          MET02550
      HLH(2,KHR)=XMN+(XAF-XMN)*((KHR-TSR)/(24.-TSR))                     MET02560
      HLH(1,KHR)=XAF*(KHR-TSR)/(24.-TSR)                                 MET02570
      GO TO 360                                                          MET02580
340   IFLAG=1                                                            MET02590
      IHOUR=0                                                            MET02600
      GO TO 370                                                          MET02610
350   HLH(1,KHR)=XAFM1+(XAF-XAFM1)*((24.-TSS+KHR)/(24.-TSS+24.))         MET02620
      HLH(2,KHR)=HLH(1,KHR)                                              MET02630
C***READ NEXT HOUR'S MET DATA                                             MET02640
360   IF (IFLAG.EQ.1) GO TO 390                                          MET02650
C***STORE CORRECT MONTH, AND DAY FOR DAILY PRINTOUT, SINCE 24TH HOUR LABEMET02660
      IF(KHR.NE.23) GO TO 365                                            MET02670
      LMON=IMONTH                                                        MET02680
      LDAY=IDAY                                                          MET02690
365   READ (8,420,END=340) ID,IYEAR,IMONTH,IDAY,IHOUR,ICEIL,IDIR,ISPEED,MET02700
     1ITEMP,ICOVER                                                       MET02710
      IREC=IREC+1                                                        MET02720
C***END OF HOUR LOOP.                                                     MET02730
370   CONTINUE                                                           MET02740
C***WRITE DAYS CALCULATION ON TO FILE                                     MET02750
C***EACH ARRAY CONTAINS THE COMPLETE INFORMATION FOR ONE DAY ORDERED      MET02760
C***SEQUENTIALLY FROM HOUR 01 THRU 24                                     MET02770
      WRITE (9) IYEAR,LMON,DAY1,KST,SPEED,TEMP,AFV,FR,HLH                MET02780
      WRITE (IO,550) IYEAR,LMON,LDAY,DAY1,TSR,TSS                        MET02790
      WRITE (IO,560) KST                                                 MET02800
      WRITE (ID,570) SPEED,TEMP,AFV,FVR,((HL(I,J),J=1,24),I=1,2)        METO2810
C***END OF DAY LOOP.                                                    METO2820
380   CONTINUE                                                          METO2830
390   WRITE (6) IYEAR,LMON,DAY1,KST,SPEED,TEMP,AFV,FVR,HL               METO2840
      WRITE (ID,550) IYEAR,LMON,LDAY,DAY1,TSR,TSS                       METO2850
      WRITE (ID,560) KST                                                METO2860
      WRITE (ID,570) SPEED,TEMP,AFV,FVR,((HL(I,J),J=1,24),I=1,2)        METO2870
      WRITE (ID,580)                                                    METO2880
      CALL EXIT                                                         METO2890
C                                                                       METO2890
400   FORMAT (I5,I2,1X,2F10.1,F2.0,I4,F10.0)                            METO2900
410   FORMAT(' STATION NUMBER=',I5,5X,'YEAR OF DATA=',I2/1X,            METO2910
     *'LATITUDE=',F10.1,'  LONGITUDE=',F10.1,'  ZONE=',F4.0/1X,         METO2920
     *'NUMBER OF DAYS IN YEAR=',I3,'  RANDOM SEED=',F10.0)              METO2930
420   FORMAT (I5,4I2,3A1,22X,2I2,4X,I3,29X,A1)                          METO2940
430   FORMAT (12X,F5.0,13X,F5.0)                                        METO2950
440   FORMAT (I5,I2,5X,F5.0,13X,F5.0)                                   METO2960
450   FORMAT (1X,'19',I2,' SURFACE DATA AT STATION ',I5,10X,'19',I2,' MIMETO2970
     1XING HEIGHT DATA AT STATION ',I5)                                 METO2980
460   FORMAT (' ID DOES NOT MATCH IN RECORD # ',I4,'  ID ON TAPE IS ',I5METO2990
     *,' ID REQUESTED IS ',I5)                                          METO3000
470   FORMAT (' YEAR IS',I3,' INSTEAD OF ',I2,' IREC=',I4)              METO3010
480   FORMAT (' MONTH ',I2,' DOES NOT AGREE WITH LOOP ',I2,' IREC=',I4) METO3020
490   FORMAT (' DAY ',I2,' DOES NOT AGREE WITH LOOP ',I2,' IREC=',I4)   METO3030
500   FORMAT (' HOUR ',I2,' DOES NOT AGREE WITH LOOP ',I2,' IREC=',I4)  METO3040
510   FORMAT (' *****DATA IS MISSING. PLEASE CORRECT INPUT FILE*****')  METO3050
520   FORMAT (' ERROR: MISSING HOUR LOOP VALUE= ',I3,' WHILE VALUE ','ONMETO3060
     1 RECORD ',I7,' IS = ',I3)                                         METO3070
530   FORMAT (' THE CHARACTER ',A1,' IS NOT ALLOWABLE.',' CLOUD COVER DEMETO3080
     1FAULTS TO 10.')                                                   METO3090
540   FORMAT (' STABILITY=',24I1)                                       METO3100
550   FORMAT (' IYEAR=',I2,' IMONTH=',I2,' DAY=',I2,' JULIAN DAY=',     METO3110
     *F5.0,' SUNRISE=',F7.3,'  SUNSET=',F7.3)                           METO3120
560   FORMAT (' KST= ',24(I1,4X))                                       METO3130
570   FORMAT (' SPEED=  ',24(F4.1,1X)/' TEMP=',24(F4.0,1X)/' AFV= ',24(FMETO3140
     14.0,1X)/' FVR=',24(F4.0,1X)/' HL1=',12(F5.0,1X)/6X,12(F5.0,1X)/' METO3150
     2HL2=',12(F5.0,1X)/6X,12(F5.0,1X))                                 METO3160
580   FORMAT (' ALL RECORDS HAVE BEEN PROCESSED')                       METO3170
C                                                                       METO3180
      END                                                               METO3190
                                                                        METO3200
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SINGLE SOURCE (CRSTER) MODEL-MAIN PROGRAM

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C---CRSTER---UNEVEN TERRAIN MODEL---                                    CV000100
      DIMENSION SOURCE(20),HCONJ(5),ELEV(5,36),COMENT(20)               CV000200
     *,IELEV(5,36),SMO(13),                                             CV000300
     *QSSN(240),VSSN(240),TSSN(240),                                    CV000400
     *ALLASK(200),LLREC(100)                                            CV000500
      COMMON JHR(17),HS(20),HP(20),TS(20),TITLE(20),IDENT(5),VF(20),    CV000600
     *D(20),GADJ(36,5),ANG(5),DA(20),IMET,VS(20)                        CV000700
      COMMON /COM2/CON1(20,19),CON3(20,19),CONN(20,19),CON24(20,19),    CV000800
     *CONAN(20,19),ISC1(20),ISC3(20),ISCN(20),ISC24(20),ISCAN(20),      CV000900
     *SC1(40),SC3(40),SCN(40),SC24(40),SCAN(40),IPR(5),ISC,LINE         CV001000
      COMMON /COM1/DAY(366),TX1(6),TX2(2),                              CV001100
     *ITAP,NS,IVT,IDCK,IVCK,ITCK,                                       CV001200
     *Q240(12,20),V240(12,20),T240(12,20)                               CV001300
      INTEGER*2 DAY                                                     CV001400
      NAMELIST/NAM1/IUR,ITAP,IPTZ,DAY,ANG,IMET,                         CV001500
     *ISS,ISY,IUS,IUY,IVT,QSSN,VSSN,TSSN,IDCK,IVCK,ITCK,                CV001600
     *ISC,SC1,SC3,SCN,SC24,SCAN                                         CV001700
      DATA ELEV/180*0./                                                 CV001800
      DATA BLKSS/'    '/                                                CV001900
      DATA DAY/366*1,2*0/                                               CV002000
      DATA IMET,ITAP,IPTZ,NS/1,0,0,0/                                   CV002100
      DATA SMO/'JAN','FEB','MAR','APR','MAY','JUN','JUL',               CV002200
     *'AUG','SEP','OCT','NOV','DEC','ALL'/                              CV002300
      EQUIVALENCE (ALLASK(1),SC1(1)),(ALLASK(41),SC3(1)),               CV002400
     *(ALLASK(81),SCN(1)),(ALLASK(121),SC24(1)),(ALLASK(161),SCAN(1)),  CV002500
     *(LLREC(1),ISC1(1)),(LLREC(21),ISC3(1)),(LLREC(41),ISCN(1)),       CV002600
     *(LLREC(61),ISC24(1)),(LLREC(81),ISCAN(1))                         CV002700
C***READ PLANT NAME AND POLLUTANT.                                      CV002800
      READ(5,100)TITLE                                                  CV002900
      DO 60 IS=1,6                                                      CV003000
   60 TX1(IS)=TITLE(IS)                                                 CV003100
      DO 70 IS=7,8                                                      CV00320.
      IX=IS-6                                                           CV003300
   70 TX2(IX)=TITLE(IS)                                                 CV003400
  100 FORMAT(20A4)                                                      C 003500
      WRITE(6,110)TX1,TX2                                               CV003600
  110 FORMAT(1H1,'PLANT NAME: ',6A4,'  POLLUTANT: ',2A4,                CV003700
     *'  EMISSION UNITS: GM/SEC  ','  AIR QUALITY UNITS: GM/M**3')      CV003800
C***READ COMMENT CARDS FOLLOWED BY ONE BLANK CARD.                      CV003900
  113 READ(5,104)COMENT                                                 CV004000
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      WRITE(6,112)COMENT                                                CV004100
  112 FORMAT(1X,20A4)                                                   CV004200
      IF(COMENT(1).NE.BLNKS)GO TO 113                                   CV004300
C***READ NAMELIST VARIABLES.                                            CV004400
      READ(5,NAM1)                                                      CV004500
      IF (ISC.EQ.0) GO TO 511                                           CV004600
C***CONVERT TO RECEPTOR NUMBER FOR SOURCE CONTRIBUTION.                 CV004700
      IM=0                                                              CV004800
      DO 111 IV=1,199,2                                                 CV004900
      IM=IM+1                                                           CV005000
      IF (ALLASK(IV).EQ.0.) GO TO 411                                   CV005100
      DO 211 JV=1,5                                                     CV005200
      IF(ALLASK(IV).EQ.RNE(JV))GO TO 1311                               CV005300
  211 CONTINUE                                                          CV005400
      WRITE(6,611)                                                      CV005500
  611 FORMAT(1H1,5X,'BAD RECEPTOR REQUESTED FOR SOURCE CONTRIBUTION     CV005600
     * - END RUN')                                                      CV005700
      STOP                                                              CV005800
 1311 LLREC(IM)=ALLASK(IV+1)+((JV-1)*36)+.1                             CV005900
      GO TO 111                                                         CV006000
  411 LLREC(IM)=0                                                       CV006100
  111 CONTINUE                                                          CV006200
C***INITIALIZE SOURCE CONTRIBUTION ARRAYS.                              CV006300
      DO 4001 IWOPS=1,20                                                CV006400
      DO 4001 IZOPS=1,19                                                CV006500
      CON1(IWOPS,IZOPS)=0.0                                             CV006600
      CON3(IWOPS,IZOPS)=0.0                                             CV006700
      CONW(IWOPS,IZOPS)=0.0                                             CV006800
      CON24(IWOPS,IZOPS)=0.0                                            CV006900
      CONAN(IWOPS,IZOPS)=0.0                                            CV007000
 4001 CONTINUE                                                          CV007100
  511 CONTINUE                                                          CV007200
C***OPEN PREPROCESSOR FILE.                                             CV007300
      READ(9)ISSI,ISYI,IUSI,IUYI                                        CV007400
C***CHECK FOR CORRECT PREPROCESSOR FILE.                                CV007500
      IF(ISS.NE.ISSI.OR.ISY.NE.ISYI.OR.IUS.NE.IUSI.OR.IUY.NE.IUYI)      CV007600
     *GO TO 832                                                         CV007700
      GO TO 833                                                         CV007800
  832 WRITE(6,834)                                                      CV007900
  834 FORMAT(' NO MATCH FOR SURFACE / UPPER AIR REQUEST')               CV008000
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      WRITE(6,835)ISS1,ISY1,ISS,ISY,IUS1,IUY1,IUS,IUY                   CV008100
      GO TO 900                                                         CV008200
  833 WRITE(6,835)ISS1,ISY1,ISS,ISY,IUS1,IUY1,IUS,IUY                   CV008300
  835 FORMAT(1H1,'MET FILE      REQUESTED'/13X,'STN NO. YR',            CV008400
     *2X,'STN NO. YR'/2X,'SURFACE      ',I5,2X,I2,4X,I5,2X,I2/2X,       CV008500
     *'UPPER AIR    ',I5,2X,I2,4X,I5,2X,I2)                             CV008600
C**EDIT NAMELIST PARAMETERS AND PRINT CONTROL COMMENTS.                  CV008700
      IF(IUR.EQ.1)WRITE(6,800)                                          CV008800
  800 FORMAT(' PLANT LOCATION: RURAL')                                  CV008900
      IF(IUR.EQ.2)WRITE(6,801)                                          CV009000
  801 FORMAT(' PLANT LOCATION: URBAN')                                  CV009100
      IF(IUR.EQ.1.OR.IUR.EQ.2)GO TO 803                                 CV009200
      WRITE(6,802)IUR                                                   CV009300
  802 FORMAT(' INVALID IUR VALUE: ',I2,', ABORT RUN')                   CV009400
      STOP                                                              CV009500
  803 IF(ITAP.EQ.0)WRITE(6,804)                                         CV009600
  804 FORMAT(' NO TAPE OUTPUT')                                         CV009700
      IF(ITAP.EQ.1)WRITE(6,805)                                         CV009800
  805 FORMAT(' OUTPUT TAPE TO BE WRITTEN ')                             CV009900
      IF(ITAP.EQ.0.OR.ITAP.EQ.1) GO TO 807                              CV010000
      WRITE(6,806)ITAP                                                  CV010100
      ITAP=0                                                            CV010200
  806 FORMAT(' INVALID ITAP VALUE: ',I2,', SET TO 0')                   CV010300
  807 IF(IQCK.EQ.1)WRITE(6,812)                                         CV010400
  812 FORMAT(' Q VALUES REQUIRE MONTHLY INPUT')                         CV010500
      IF(IVCK.EQ.1)WRITE(6,813)                                         CV010600
  813 FORMAT(' V VALUES REQUIRE MONTHLY INPUT')                         CV010700
      IF(ITCK.EQ.1)WRITE(6,814)                                         CV010800
  814 FORMAT(' T VALUES REQUIRE MONTHLY INPUT')                         CV010900
      IF(IMET.EQ.0)WRITE(6,815)                                         CV011000
  815 FORMAT(' MET DATA WILL NOT BE PRINTED')                           CV011100
      IF(IPTZ.LT.0.OR.IPTZ.GT.1)WRITE(6,817)IPTZ                        CV011200
      IF(IPTZ.LT.0.OR.IPTZ.GT.1)IPTZ=0                                  CV011300
  817 FORMAT(' INVALID IPTZ VALUE: ',I2,', SET TO 0')                   CV011400
      IF(IVT.EQ.0.OR.IVT.EQ.2.OR.IVT.EQ.4.OR.IVT.EQ.6.OR.IVT.EQ.8.      CV011500
     *OR.IVT.EQ.12)GO TO 571                                            CV011600
      WRITE(6,572)IVT                                                   CV011700
  572 FORMAT(' INVALID IVT VALUE: ',I2,', SET TO 0')                    CV011800
      IVT=0                                                             CV011900
  571 WRITE(6,522)(IDAY(IJ),IJ=1,366)                                   CV012000
  522 FORMAT(/' DAY---',6(5(10I2,2X)/6X))                                CV0012100
      WRITE(6,574)                                                       CV0012200
  574 FORMAT(///20(' *'),' N O T E',20(' *'),                            CV0012300
     *//10X,' ALL TABLES, INCLUDING SOURCE CONTRIBUTION, THAT CONTAIN',  CV0012400
     *' "ANNUAL" IN THE HEADING ARE BASED ONLY ON THOSE DAYS',           CV0012500
     */,10X,' MARKED BY "1" IN THE ABOVE TABLE')                         CV0012600
      WRITE(6,120)                                                       CV0012700
  120 FORMAT(1H1/)                                                       CV0012800
      WRITE(6,599)RNG                                                    CV0012900
  599 FORMAT('    RING DISTANCES(KM):',5F7.2)                            CV0013000
C***IF REQUIRED, READ ELEVATIONS FOR PLANT AND RECEPTORS.                 CV0013100
  152 IF(IPTZ.EQ.1)READ(5,270)PELEH                                      CV0013200
      IF(IPTZ.EQ.1)PELEV=PELEH*0.3048006                                 CV0013300
      WRITE(6,254)PELEH,PELEV                                            CV0013400
  254 FORMAT(//' PLANT ELEVATION (FEET ABOVE SEA LEVEL)---',F10.1,       CV0013500
     *T60,' PLANT ELEVATION (METERS ABOVE SEA LEVEL)---',F10.1//         CV0013600
     *5X,'RECEPTOR ELEVATIONS (FEET ABOVE SEA LEVEL)',                   CV0013700
     *T65,'RECEPTOR ELEVATIONS (METERS ABOVE SEA LEVEL)',//1X,           CV0013800
     *'DIRECTION    RING#1    RING#2    RING#3    RING#4    RING#5',     CV0013900
     *T73,'RING#1    RING#2    RING#3    RING#4    RING#5'/)             CV0014000
      IF(IPTZ.EQ.0)GO TO 701                                             CV0014100
  253 READ(5,251)IJ,HCONJ                                                CV0014200
  251 FORMAT(I2,4X,5F10.0)                                               CV0014300
      IF(IJ.EQ.0)GO TO 261                                               CV0014400
      DO 252 I=1,5                                                       CV0014500
      ELEH(I,IJ)=HCONJ(I)                                                CV0014600
      ELEV(I,IJ)=HCONJ(I)*0.3048006                                      CV0014700
  252 CONTINUE                                                           CV0014800
      GO TO 253                                                          CV0014900
  701 PELEV=0.0                                                          CV0015000
      PELEH=0.0                                                          CV0015100
      DO 702 I2=1,5                                                      CV0015200
      DO 702 I21=1,36                                                    CV0015300
      ELEH(I2,I21)=0.0                                                   CV0015400
  702 ELEV(I2,I21)=0.0                                                   CV0015500
  261 DO 262 J=1,36                                                      CV0015600
C***PRINT ELEVATION DATA FOR RECEPTORS.                                   CV0015700
      WRITE(6,255)J,(ELEH(I,J),I=1,5),(ELEV(K,J),K=1,5)                  CV0015800
  255 FORMAT(I7,3X,5F9.1,T70,5F9.1)                                      CV0015900
      DO 263 J=1,5                                                       CV0016000
  263 BADJ(I,J)=ZELE(J,I)-RELEV)                                    CV016100
  262 CONTINUE                                                      CV016200
C***INPUT SOURCES TO BE CONSIDERED                                  CV016300
  526 WRITE(6,120)                                                  CV016400
  260 NS=NS+1                                                       CV016500
      IF(NS.GT.20)WRITE(6,573)                                      CV016600
  573 FORMAT(3X,'***   ***  MAXIMUM OF 19 STACKS EXCEEDED',         CV016700
     *' - - - RUN TERMINATED')                                      CV016800
      IF(NS.GT.20)GO TO 900                                         CV016900
C***READ DATA FOR ONE STACK.                                         CV017000
      READ(5,100,END=500)SOURCE                                     CV017100
      READ(5,270)Q,HP(NS),D(NS),VS(NS),TS(NS)                       CV017200
  270 FORMAT(F10.4,10X,4F10.2)                                      CV017300
      IF(HP(NS).LE.0.001) GO TO 499                                 CV017400
      QS(NS)=Q                                                      CV017500
C***PRINT STACK IDENTIFICATION.                                      CV017600
      WRITE(6,300)NS,SOURCE                                         CV017700
  300 FORMAT(' STACK #',I3,'---',20A4)                              CV017800
      GO TO 260                                                     CV017900
  499 WRITE(6,498)                                                  CV018000
  500 NS=NS-1                                                       CV018100
C***CHECK FOR MONTHLY STACK DATA.                                    CV018200
      IF(IQCK.EQ.1)GO TO 550                                        CV018300
C***ANNUAL EMISSIONS INPUT.                                          CV018400
      DO 551 I2=1,NS                                                CV018500
      DO 551 I3=1,12                                                CV018600
  551 QZ40(I3,I2)=QS(I2)                                            CV018700
      GO TO 552                                                     CV018800
C***TRANSFER MONTHLY EMISSIONS.                                      CV018900
  550 DO 553 I2=1,NS                                                CV019000
      DO 553 I3=1,12                                                CV019100
      I4=(I2-1)*12+I3                                               CV019200
  553 QZ40(I3,I2)=QSSN(I4)                                          CV019300
  552 IF(IVCK.EQ.1)GO TO 554                                        CV019400
C***ANNUAL EXIT VELOCITIES INPUT.                                    CV019500
      DO 555 I2=1,NS                                                CV019600
      DO 555 I3=1,12                                                CV019700
  555 VZ40(I3,I2)=VS(I2)                                            CV019800
      GO TO 557                                                     CV019900
C***TRANSFER MONTHLY EXIT VELOCITIES.                                CV020000
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  554 DO 556 I2=1,NS                                                    CV020100
      DO 556 I3=1,12                                                    CV020200
      I4=(I2-1)*12+I3                                                   CV020300
  556 Q2N0(I3,I2)=QSSN(I4)                                              CV020400
  557 IF(ITCK.EQ.1)GO TO 558                                            CV020500
C***ANNUAL TEMPERATURES INPUT.                                           CV020600
      DO 559 I2=1,NS                                                    CV020700
      DO 559 I3=1,12                                                    CV020800
  559 T2N0(I3,I2)=TS(I2)                                                CV020900
      GO TO 570                                                         CV021000
C***TRANSFER MONTHLY TEMPERATURES.                                       CV021100
  558 DO 560 I2=1,NS                                                    CV021200
      DO 560 I3=1,12                                                    CV021300
      I4=(I2-1)*12+I3                                                   CV021400
  560 T2N0(I3,I2)=TSSN(I4)                                              CV021500
  570 IF(IPTZ.EQ.0)GO TO 581                                            CV021600
      HPL=1000.0                                                        CV021700
      IHPL=0                                                            CV021800
      DO 566  I7=1,NS                                                   CV021900
      IF(HP(I7).LT.HPL)HPL=HP(I7)                                       CV022000
  566 CONTINUE                                                          CV022100
C***COMPARE STACK AND RECEPTOR HEIGHTS.                                  CV022200
      HPL=HPL+PELEV                                                     CV022300
      DO 567  I7=1,5                                                    CV022400
      DO 567  I8=1,36                                                   CV022500
      IF(ELEV(I7,I8).GT.HPL)WRITE(6,568)                                CV022600
  568 FORMAT(3X,'***   ***  RECEPTOR HEIGHT GREATER THAN ',             CV022700
     *'HEIGHT OF LOWEST STACK - - - RUN TERMINATED')                    CV022800
      IF(ELEV(I7,I8).GT.HPL)STOP                                        CV022900
      IF(ELEV(I7,I8).LT.PELEV)IHPL=IHPL+1                               CV023000
  569 FORMAT(3X,'RECEPTOR ELEVATION LESS THAN PLANT ',                  CV023100
     *'ELEVATION - - - RECEPTOR ELEVATION SET TO PLANT ',               CV023200
     *'ELEVATION - ',I3,' TIMES')                                       CV023300
      IF(ELEV(I7,I8).LT.PELEV)ELEV(I7,I8)=PELEV                         CV023400
  567 CONTINUE                                                          CV023500
      IF(IHPL.GT.0)WRITE(6,569)IHPL                                     CV023600
C***PRINT DATA FOR EACH STACK.                                           CV023700
  581 WRITE(6,318)                                                      CV023800
  318 FORMAT(/' STACK    MONTH      EMISSION RATE         HEIGHT    DIAMCV023900
     *ETER  EXIT VELOCITY   TEMP        VOLUMETRIC FLOW',               CV024000
     */16X,T25,'(GMS/SEC)',T43,'(METERS)   (METERS)      (M/SEC)',      CV024100
     *T79,'(DEG.K)        (M**3/SEC)')                                   CV024200
      IF(ISCK.EQ.1.OR.IVCK.EQ.1.OR.ITCK.EQ.1)GO TO 823                   CV024300
C***STACK DATA IS ON ANNUAL BASIS.                                       CV024400
      DO 311 IS=1,NS                                                     CV024500
C***CALCULATE VOLUMETRIC FLOW RATE FOR EACH STACK FOR PRINTING ONLY.     CV024600
      DO 561 I3=1,12                                                     CV024700
  561 VF(IS)=0.785398*V240(I3,IS)*D(IS)**2                               CV024800
      WRITE(6,312)IS,SMO(13),QQ(IS),HP(IS),D(IS),VS(IS),                 CV024900
     *TS(IS),VF(IS)                                                      CV025000
  312 FORMAT(/I6,6X,A4,F16.4,F17.2,F10.2,F13.2,F13.2,F15.2,F15.2)        CV025100
  311 CONTINUE                                                           CV025200
      GO TO 822                                                          CV025300
C***STACK DATA IS ON MONTHLY BASIS.                                      CV025400
  823 DO 824 I2=1,NS                                                     CV025500
C***CALCULATE VOLUMETRIC FLOW RATE FOR PRINTING ONLY.                    CV025600
      IF(I2.EQ.4.OR.I2.EQ.7.OR.I2.EQ.10.OR.I2.EQ.13.OR.I2.EQ.16)         CV025700
     *WRITE(6,825)                                                       CV025800
  825 FORMAT(1H1,'  STACK    MONTH      EMISSION RATE       HEIGHT      CV025900
     *DIAMETER  EXIT VELOCITY   TEMP       VOLUMETRIC FLOW',             CV026000
     */16X,T25,'(GMS/SEC)',T43,'(METERS)   (METERS)      (M/SEC)',      CV026100
     *T79,'(DEG.K)        (M**3/SEC)')                                   CV026200
      DO 824 I3=1,12                                                     CV026300
      VF(I2)=.785398*V240(I3,I2)*D(NS)**2                                CV026400
      IF(I3.EQ.1)WRITE(6,826)I2,SMO(I3),Q240(I3,I2),HP(I2),D(I2),        CV026500
     *V240(I3,I2),T240(I3,I2),VF(I2)                                     CV026600
      IF(I3.GT.1)WRITE(6,827)SMO(I3),Q240(I3,I2),HP(I2),D(I2),           CV026700
     *V240(I3,I2),T240(I3,I2),VF(I2)                                     CV026800
  824 CONTINUE                                                           CV026900
  826 FORMAT(/I6,6X,A4,F16.4,F17.2,F10.2,F13.2,F13.2,F15.2,F15.2)        CV027000
  827 FORMAT(12X,A4,F16.4,F17.2,F10.2,F13.2,F13.2,F15.2,F15.2)           CV027100
C***CHECK DAY ARRAY FOR INVALID DATA; IF INVALID, SET TO ZERO.           CV027200
  822 DO 512 I=1,366                                                     CV027300
      IF(DAY(I).NE.0.AND.DAY(I).NE.1)DAY(I)=0                            CV027400
  512 CONTINUE                                                           CV027500
C***CALL SUBROUTINE CRS.                                                 CV027600
  515 CALL CRS(IUR,KSTL)                                                 CV027700
  498 FORMAT(///8A)                                                      CV027800
  400 STOP                                                               CV027900
      END                                                                CV028000
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SINGLE SOURCE (CRSTER) MODEL - SUBROUTINE CPS

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      SUBROUTINE CPS(IUR,KSTL)                                          CP000100
      COMMON /CCM2/CCN1(20,19),CON3(20,19),CON4(20,19),CON24(20,19),    CP000200
     *CONA(20,19),ISC1(20),ISC3(20),ISC4(20),ISC24(20),ISCAN(20),       CP000300
     *SC1(40),SC3(40),SC4(40),SC24(40),SCAN(40),IPR(5),ISC,LINE         CP000400
      COMMON JR,IMO,DAY1,ISTAR(24),AWS(24),TEMP(24),AFV(24),AFVR(24),   CP000500
     *HLH(24,2),KS(20),HP(20),TS(20),TITLE(20),IDENT(5),VF(20),D(20),   CP000600
     *ADJ(180),PHG(5),QQ(20),IMET,VS(20)                                CP000700
      DIMENSION DTH(11),IHC(4),SYD(5,6),SZD(5,6),P(6),LOOP(6,2),        CP000800
     *CHI24(180),DMAX(180),DMAXYR(4),                                   CP000900
     *CHIAN(180),DMAXAN(180),JMAX1(180),DMAX2(180)                      CP001000
     *,MMM(2),CHI25(180),GTAPE1(36,5),GTAPE2(36,5),GTAPE3(36,5),        CP001100
     *TAPIN(171),JMAX3(4),CHI(180),HE(20),DD(366)                       CP001200
     *,CHIV(180),CHIVM(180),CHIHM(180),CHIVM2(180),                     CP001300
     *CHIHM2(180),DX(5),JM(5),IUMI(180),RLH(48),                        CP001400
     *CHIS(180),CHISM(180),CHISMC(180),XV1(50),AV1(50),                 CP001500
     *XV2(50),AV2(50),XV3(50),AV3(50)                                   CP001600
      COMMON /CCM1/DAY(366),TX1(6),TX2(2),                              CP001700
     *ITAP,YS,IWT,IDCX,IYCX,ITCX,                                       CP001800
     *Q240(12,20),H240(12,20),T240(12,20)                               CP001900
      INTEGER*2 DAY,JMAX1(180),SAB(180,2),SUB(36,5),JDD(366),KEY(366)   CP002000
     *,JMAX12(180),JMVD(180),JMVC(180),JMVD2(180),JMVC2(180),           CP002100
     *JMHD(180),JMHM(180),JMHD2(180),JMHM2(180),                        CP002200
     *KMVD(180),KMVD2(180),KMVC(180),KMVC2(180)                         CP002300
      DATA HMAXT,DMAXT,KKK,KMM/0.,0.,1,1,1/                             CP002400
      EQUIVALENCE (GTAPE1(1),CHI(1)),(GTAPE2(1),CHI25(1)),(GTAPE3(1),   CP002500
     *CHI24(1)),(TAPIN(1),JR),(DMAXYR(1),JMAX3(1)),(DX(1),JM(1))        CP002600
      DATA IHC,P/6,13,18,24,.1,.15,.2,.25,.3,.3/                        CP002700
      DATA DTH/-50.,-40.,-30.,-20.,-10.,0.,10.,20.,30.,40.,50./         CP002800
      DATA LOOP/1,1,2,3,4,4,11,11,10,9,8,8/                             CP002900
      DATA SAB/36*1,36*2,36*3,36*4,36*5,                                CP003000
     *1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,         CP003100
     *23,24,25,26,27,28,29,30,31,32,33,34,35,36,1,2,3,4,5,6,7,8,9,10,11,CP003200
     *12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,CP003300
     *34,35,36,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,CP003400
     *23,24,25,26,27,28,29,30,31,32,33,34,35,36,1,2,3,4,5,6,7,8,9,10,11,CP003500
     *12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,CP003600
     *34,35,36,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,CP003700
     *23,24,25,26,27,28,29,30,31,32,33,34,35,36/                        CP003800
      DATA SUB/1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,CP003900
     *23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,CP004000
     *45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,CR004100
     *67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,CR004200
     *89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,  CR004300
     *108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,   CR004400
     *124,125,126,127,128,129,130,131,132,133,134,135,136,137,138,139,   CR004500
     *140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,   CR004600
     *156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,   CR004700
     *172,173,174,175,176,177,178,179,180/                               CR004800
      TDAY=366.                                                          CR004900
      IFIR=0                                                             CR005000
C***PRESET CUMULATIVE CONCENTRATIONS TO ZERO                             CR005100
      DO 150 I=1,180                                                     CR005200
      CHI24(I)=0.                                                        CR005300
      CHIVM(I)=0.0                                                       CR005400
      CHIVM2(I)=0.0                                                      CR005500
      DHIVM(I)=0.0                                                       CR005600
      DHIVM2(I)=0.0                                                      CR005700
      DMAX2(I)=0.0                                                       CR005800
      CHI4M(I)=0.0                                                       CR005900
  150 DMAX(I)=0.                                                         CR006000
      DO 151 J=1,4                                                       CR006100
  151 DMAXYR(J)=0.                                                       CR006200
      DO 152 J=1,366                                                     CR006300
      IDD(J)=-1.                                                         CR006400
      IHRAN=IHRAN+(IDAY(J)*24)                                           CR006500
  152 JDD(J)=J                                                           CR006600
C***SET SWITCHES FOR VARIABLE HOUR AND 3-HOUR CONTROL                    CR006700
      ISW1=1                                                             CR006800
      ISW2=1                                                             CR006900
C***CALCULATE AND STORE SIGMAS FOR 6 STAB. & 5 DIST.                     CR007000
C***DISTANCE IS ASSUMED TO BE IN KILOMETERS***                           CR007100
      DO 250 J=1,5                                                       CR007200
      X=RNG(J)                                                           CR007300
      DO 250 KST=1,6                                                     CR007400
      CALL SIGMA(X,0,KST,SY,SZ)                                          CR007500
      SYD(J,KST)=SY                                                      CR007600
  250 SZD(J,KST)=SZ                                                      CR007700
C***BEGIN LOOP ON DAYS***                                                CR007800
      IMOX=0                                                             CR007900
      DO 5000 IDY=1,366                                                  CR008000
      IF(DAY(IDY).EQ.1)GO TO 1000                                       CR008100
      TDAY=TDAY-1.0                                                     CR008200
      IF(IDY.EQ.366.AND.DAY(IDY).EQ.0)GO TO 5000                        CR008300
      IF(DAY(IDY+1).EQ.1)GO TO 1490                                     CR008400
      READ(9)JHR                                                        CR008500
 1499 FORMAT(A4)                                                        CR008600
      GO TO 5000                                                        CR008700
C***READ STABILITY FROM THE HOUR BEFORE THE FIRST HOUR TO BE USED        CR008800
 1490 READ(9)JHR,IMO,DAY1,ISTAB                                         CR008900
C***DO NOT ALLOW THESE FIRST TWO STABILITIES TO CHANGE TOO FAST          CR009000
      KSTL=ISTAB(1)                                                     CR009100
      DO 1496 IHR=2,24                                                  CR009200
      KSTT=ISTAB(IHR)-KSTL                                              CR009300
      IF(KSTT.GT.1)ISTAB(IHR)=KSTL+1                                    CR009400
      IF(KSTT.LT.-1)ISTAB(IHR)=KSTL-1                                   CR009500
 1496 KSTL=ISTAB(IHR)                                                   CR009600
      GO TO 5000                                                        CR009700
C***RE-INITIALIZE DAILY AVERAGE AT BEGINNING OF EACH DAY***              CR009800
 1000 DO 1310 IR=1,180                                                  CR009900
 1310 CH125(IR)=1.0E-30                                                 CR010000
      IMAXT=0.                                                          CR010100
      HMAXT=0.                                                          CR010200
C***INPUT INFORMATION FROM MET FILE***                                   CR010300
      READ(9)JHR,IMO,DAY1,ISTAB,AWS,TEMP,AFV,AFVR,HLH                   CR010400
      IF(IMOX.EQ.1)GO TO 8039                                           CR010500
      IMOX=1                                                            CR010600
      GO TO 8041                                                        CR010700
 8039 IF(IDM.EQ.IMO)GO TO 8042                                          CR010800
 8041 IDM=IMO                                                           CR010900
C***CALCULATE STACK GAS VOLUME FLOW RATE FOR PLUME RISE CALCULATIONS     CR011000
      DO 8043 I2=1,NS                                                   CR011100
      VF(I2)=0.785398*Q246(IMO,I2)*D(I2)**2                             CR011200
      TS(I2)=T248(IMO,I2)                                               CR011300
 8043 VS(I2)=Q248(IMO,I2)                                               CR011400
C***RESTRUCTURE MIXING HEIGHT ARRAYS                                     CR011500
 8042 DO 1010 I=1,2                                                     CR011600
      DO 1010 J=1,24                                                    CR011700
      K=(I-1)*24+J                                                      CR011800
 1010 RLH(K)=HLH(J,I)                                                   CR011900
      DO 1020 I=1,48,2                                                  CR012000
      J=(I/2)+1                                                         CR012100
 1020 HLH(J,1)=RLH(I)                                                   CR012200
      DO 1030 I=2,48,2                                                  CR012300
      J=(I/2)                                                           CR012400
 1030 HLH(J,2)=RLH(I)                                                   CR012500
      IF(IMET.EQ.0)GO TO 1199                                           CR012600
      IF(IDY.EQ.1)WRITE(6,8030)                                         CR012700
 8030 FORMAT('1','   ')                                                 CR012800
      WRITE(6,1500)TAPIN                                                CR012900
 1500 FORMAT(//' JYR=',I2,' IMO=',I2,' JDAY=',F4.0/' ISTAB=',I3,23I5/   CR013000
     *' AWS=',24F5.1/' TEMP=',24F5.0/' AFV= ',24F5.0/                   CR013100
     *' AFVR=',24F5.0/' HLH1=',12F6.0/6X,12F6.0/' HLH2=',12F6.0/6X,     CR013200
     *12F6.0/)                                                          CR013300
C***LOOP ON HOURS                                                       CR013400
 1199 ICALC=0                                                           CR013500
      IF(IDY.EQ.1)KSTL=ISTAB(1)                                         CR013600
      DO 4201 IHR=1,24                                                  CR013700
C***RESET RECEPTOR CONCENTRATIONS TO NEAR ZERO (1.0E-30)                CR013800
      DO 1200 IR=1,180                                                  CR013900
 1200 CHI(IR)=1.0E-30                                                   CR014000
      RWS=AWS(IHR)                                                      CR014100
      FV=AFV(IHR)                                                       CR014200
      FVR=AFVR(IHR)                                                     CR014300
      IF(FVR.LE.5.)FVR=FVR+360.                                         CR014400
      XMH=HLH(IHR,IUR)                                                  CR014500
      T=TEMP(IHR)                                                       CR014600
C***DO NOT ALLOW STABILITY TO VARY RAPIDLY                              CR014700
      IF((ISTAB(IHR)-KSTL).GT.1) GO TO 1600                             CR014800
      GO TO 1615                                                        CR014900
 1600 ISTAB(IHR)=KSTL+1                                                 CR015000
      GO TO 1620                                                        CR015100
 1615 IF((KSTL-ISTAB(IHR)).GT.1)  ISTAB(IHR)=KSTL-1                     CR015200
 1620 IF(IUR.NE.2) GO TO 1630                                           CR015300
      IF(ISTAB(IHR).GT.4) ISTAB(IHR)=4                                  CR015400
 1630 KST=ISTAB(IHR)                                                    CR015500
      KSTL=KST                                                          CR015600
C***IF STABILITY=7 THE PLUME DOES NOT GET TO THE GROUND***              CR015700
      IF(ISTAB(IHR).EQ.7) GO TO 4000                                    CR015800
C***SET RANGE OF DIRECTIONS WHICH MIGHT BE AFFECTED BY THE PLUME        CR015900
      ILOW=LOOP(KST,1)                                                  CR016000
      ITOP=LOOP(KST,2)                                                  CR016100
C***DETERMINE WIND SPEED AT TOP OF STACK AND PLUME RISE FOR EACH SOURCE CR016200
      DO 1800 IS=1,NS                                                   CR016300
      WS(IS)=UWS*((HP(IS)/7.)**P(KST))                                  CR016400
      WSIS=WS(IS)                                                       CR016500
      TSIS=TS(IS)                                                       CR016600
      VFIS=VF(IS)                                                       CR016700
C***FOR STABLE CASES, ASSUME LAPSE RATES OF 0.02 DEG C/METER FOR        CR016800
C***E STABILITY AND 0.035 DEG C/METER FOR F STABILITY FOR THE           CR016900
C***PLUME RISE CALCULATIONS                                             CR017000
      IF(KST-5)1771,1775,1776                                           CR017100
 1771 DTHDZ=0.                                                          CR017200
      GO TO 1777                                                        CR017300
 1775 DTHDZ=0.02                                                        CR017400
      GO TO 1777                                                        CR017500
 1776 DTHDZ=0.035                                                       CR017600
 1777 DUMP=0.                                                           CR017700
      DUMH=0.                                                           CR017800
      DUMD=0.                                                           CR017900
      DUMVS=0.                                                          CR018000
      HPIS=HP(IS)                                                       CR018100
C***CALCULATE PLUME RISE                                                CR018200
      CALL BEHD72(HEIS,DUMHH,DUMHHN,DUMF,DHA,DUMDSF,DUMDHH,             CR018300
     *HPIS,TSIS,DUMVS,DUMD,VFIS,KST,WSIS,DUMH,DTHDZ,T,DUMP)             CR018400
      HE(IS)=HEIS                                                       CR018500
 1800 CONTINUE                                                          CR018600
C***LOOP ON DIRECTIONS***                                               CR018700
C***LOOK AT ALL DIRECTIONS WHICH COULD BE AFFECTED BY THE PLUME         CR018800
      DO 3501 IDT=ILOW,ITOP                                             CR018900
      DIR=FV+DTH(IDT)                                                   CR019000
      IDIR=DIR/10.                                                      CR019100
      IF(IDIR.LE.0)  GO TO 1810                                         CR019200
      IF(IDIR.LE.36)  GO TO 1820                                        CR019300
      IDIR=IDIR-36                                                      CR019400
      GO TO 1820                                                        CR019500
 1810 IDIR=IDIR+36                                                      CR019600
 1820 CONTINUE                                                          CR019700
      ICALC=1                                                           CR019800
      ANG=(FVR-DIR)/57.29578                                            CR019900
C***CALCULATE YO (OFF-CENTERLINE DISTANCE) AND CONCENTRATIONS FOR EACH**CR020000
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C***D IS IN METERS                                                     CR020100
      DO 3500 J=1,5                                                    CR020200
      IR=IIIR+36*(J-1)                                                 CR020300
      YD=RNG(J)*ANG*0700.                                              CR020400
      SY=SYD(J,KST)                                                    CR020500
      SZ=SZD(J,KST)                                                    CR020600
C***CALCULATE THE EXPONENTIAL TERMS OF THE GAUSSIAN PLUME EQUATION     CR020700
      C1=0.5*(YD/SY)**2                                                CR020800
      IF(C1.GE.50.)GO TO 3500                                          CR020900
      C2=2.*SZ*SZ                                                      CR021000
      AAA=1./(6.2832*SY*SZ*EXP(C1))                                    CR021100
C***LOOP ON SOURCES***                                                 CR021200
      IF(XMH.LE.0.)GO TO 3500                                          CR021300
      CHEK=SZ/XMH                                                      CR021400
      FADJ=HADJ(IR)                                                    CR021500
      DO 2000 IH=1,NS                                                  CR021600
      U=WS(IH)                                                         CR021700
      H=HE(IH)+FADJ                                                    CR021800
C***IF THE PLUME IS ABOVE THE LID, NO CONCENTRATION IS ADDED           CR021900
      IF(H.GT.XMH)GO TO 2000                                           CR022000
      AA=0.                                                            CR022100
C***IF SIGMA Z.GE.1.6*MIXING HEIGHT, ASSUME UNIFORM MIXING OF THE      CR022200
C***PLUME THRU THE MIXING LAYER                                        CR022300
      IF(CHEK.GE.1.6) GO TO 2400                                       CR022400
      A1=AAA/U                                                         CR022500
      IF(A1.LT.1.0E-30) GO TO 2000                                     CR022600
C***CALCULATE MULTIPLE REFLECTION TERMS OF THE DIFFUSION EQUATION      CR022700
C***WHEN SIGMA Z.LT.1.6*MIXING HEIGHT                                  CR022800
      C3=H*H/C2                                                        CR022900
      A2=0.                                                            CR023000
      IF(C3.LT.50.)A2=2./EXP(C3)                                       CR023100
      SUM=0.                                                           CR023200
      THL=2.*XMH                                                       CR023300
 2120 AN=AN+1.                                                         CR023400
      CS=AN*THL                                                        CR023500
      CC=H-CS                                                          CR023600
      CE=H+CS                                                          CR023700
      CN=CC*CC/C2                                                      CR023800
      CB=CE*CE/C2                                                      CR023900
      AA=0.                                                            CR024000
      AB=0.                                                             CR024100
      IF(C6.LT.50.)AA=2./EXP(C6)                                        CR024200
      IF(C8.LT.50.)AB=2./EXP(C8)                                        CR024300
      TOT=AA+AB                                                         CR024400
      SUM=SUM+TOT                                                       CR024500
      IF(TOT.LT..01)GO TO 2350                                          CR024600
      IF(XY.LT.45.)GO TO 2120                                           CR024700
      WRITE(6,2275)RNG(J),YD,H,TOT,SUM                                  CR024800
 2275 FORMAT(1X,'X GREATER THAN 45',/,6X,'X= ',F7.0,5X,'YD= ',F7.0,5X,  CR024900
     *'H = ',F5.1,5X,'TOT = ',F7.3,5X,'SUM = ',F7.3)                    CR025000
C***CALCULATE NORMALIZED RECEPTOR CONCENTRATION DUE TO THIS STACK       CR025100
 2350 RC=A1*(A2+SUM)                                                    CR025200
      GO TO 2410                                                        CR025300
C***LIMITED MIXING EQUATION FOR CONCENTRATION                           CR025400
 2400 RC=1./(2.5066*SY*HMIX*U*EXP(C1))                                  CR025500
 2410 CONTINUE                                                          CR025600
      CHI(IR)=CHI(IR)+RC*QQ(IH)                                         CR025700
      IF(ISC.EQ.0)GO TO 123                                             CR025800
C***SUM SOURCE CONTRIBUTIONS FOR SELECTED RECEPTORS.                    CR025900
      SCCON=RC*QQ(IH)                                                   CR026000
      IF(ISC1(1).EQ.0)GO TO 223                                         CR026100
C***HOURLY SOURCE CONTRIBUTIONS REQUESTED                               CR026200
      DO 122 JUM=1,20                                                   CR026300
      IF(ISC1(JUM).NE.IR)GO TO 122                                      CR026400
      CON1(JUM,IH)=SCCON                                                CR026500
      GO TO 223                                                         CR026600
  122 CONTINUE                                                          CR026700
  223 IF(ISC3(1).EQ.0)GO TO 224                                         CR026800
C***3-HOUR SOURCE CONTRIBUTIONS REQUESTED                               CR026900
      DO 225 JUM=1,20                                                   CR027000
      IF(ISC3(JUM).NE.IR)GO TO 225                                      CR027100
      CON3(JUM,IH)=CON3(JUM,IH)+SCCON                                   CR027200
      GO TO 224                                                         CR027300
  225 CONTINUE                                                          CR027400
  224 IF(ISCN(1).EQ.0)GO TO 226                                         CR027500
C***VARIABLE HOUR SOURCE CONTRIBUTIONS REQUESTED                        CR027600
      DO 227 JUM=1,20                                                   CR027700
      IF(ISCN(JUM).NE.IR)GO TO 227                                      CR027800
      CONN(JUM,IH)=CONN(JUM,IH)+SCCON                                   CR027900
      GO TO 226                                                         CR028000
  227 CONTINUE                                                          CR028100
  226 IF(ISC24(1).EQ.0)GO TO 228                                        CR028200
C***24-HOUR SOURCE CONTRIBUTIONS REQUESTED                              CR028300
      DO 229 JUM=1,20                                                   CR028400
      IF(ISC24(JUM).NE.IR)GO TO 229                                     CR028500
      CON24(JUM,IH)=CON24(JUM,IH)+SCCON                                 CR028600
      GO TO 228                                                         CR028700
  229 CONTINUE                                                          CR028800
  228 IF(ISCAN(1).EQ.0)GO TO 123                                        CR028900
C***ANNUAL SOURCE CONTRIBUTIONS REQUESTED                                CR029000
      DO 230 JUM=1,20                                                   CR029100
      IF(ISCAN(JUM).NE.IR)GO TO 230                                     CR029200
      CONAN(JUM,IH)=CONAN(JUM,IH)+SCCON                                 CR029300
      GO TO 123                                                         CR029400
  230 CONTINUE                                                          CR029500
  123 CONTINUE                                                          CR029600
 2800 CONTINUE                                                          CR029700
      CH=CHI(IR)                                                        CR029800
      IF(CH.LE.HMAXT)GO TO 2851                                         CR029900
C***SAVE MAX 1-HOUR CONC FOR THIS 24-HOUR PERIOD                         CR030000
C***SPECIFY RECEPTOR WHERE MAX OCCURRED                                  CR030100
      HMAXT=CH                                                          CR030200
      MM(1)=IR                                                          CR030300
      MM(2)=IH                                                          CR030400
C***ACCUMULATE 24-HOUR CONCENTRATIONS FOR EACH RECEPTOR                  CR030500
 2851 CHI25(IR)=CHI25(IR)+CH                                            CR030600
 3500 CONTINUE                                                          CR030700
 3501 CONTINUE                                                          CR030800
C***END OF RANGES AND AZIMUTHS                                           CR030900
C***STORE HOURLY VALUES FOR HIGH, SECOND HIGH, AND HIGH 50 TABLES        CR031000
      DO 8011 IY=1,36                                                   CR031100
      DO 8011 IZ=1,5                                                    CR031200
      IR=SUB(IY,IZ)                                                     CR031300
      IF(CHI(IR).LT.HI1(50))GO TO 3300                                  CR031400
      KVIT=(IDY*1000000)+(IR*100)+IH                                    CR031500
      DO 3306 IS=50,2,-1                                                CR031600
      ISJ=IS-1                                                          CR031700
      IF(HI1(ISJ).LT.CHI(IR))GO TO 3301                                 CR031800
      GO TO 3302                                                        CR031900
 3301 HI1(IS)=HI1(ISJ)                                                  CR032000
 3306 KXV1(IG)=KXV1(IGJ)                                                 CM032100
      GO TO 3303                                                          CM032200
 3302 HXV1(IG)=CHI(IR)                                                    CM032300
      KXV1(IG)=KXV1T                                                      CM032400
      GO TO 3300                                                          CM032500
 3303 HXV1(IGJ)=CHI(IR)                                                   CM032600
      KXV1(IGJ)=KXV1T                                                     CM032700
 3300 IF(CHI(IR).LE.CHIHR(IR))GO TO 8020                                  CM032800
      CHIHR2(IR)=CHIHR(IR)                                                CM032900
      CHIHR(IR)=CHI(IR)                                                   CM033000
      JHHD2(IR)=JHHD(IR)                                                  CM033100
      JHHD(IR)=IDY                                                        CM033200
      JHHH2(IR)=JHHH(IR)                                                  CM033300
      JHHH(IR)=IHR                                                        CM033400
      GO TO 8011                                                          CM033500
 8020 IF(CHI(IR).LE.CHIHR2(IR))GO TO 8011                                 CM033600
      CHIHR2(IR)=CHI(IR)                                                  CM033700
      JHHD2(IR)=IDY                                                       CM033800
      JHHH2(IR)=IHR                                                       CM033900
 8011 CONTINUE                                                            CM034000
C***COMPUTE AND STORE 3-HOUR VALUES FOR HIGH, SECOND HIGH, AND           CM034100
C****HIGH 50 TABLES                                                       CM034200
 4000 IF(ISW1.EQ.1) GO TO 8006                                            CM034300
      DO 8012 IY=1,36                                                     CM034400
      DO 8012 IZ=1,5                                                      CM034500
      IR=SUB(IY,IZ)                                                       CM034600
 8012 CHIV(IR)=CHIV(IR)+CHI(IR)                                           CM034700
      GO TO 8007                                                          CM034800
 8006 ISW1=0                                                              CM034900
      DO 8013 IY=1,36                                                     CM035000
      DO 8013 IZ=1,5                                                      CM035100
      IR=SUB(IY,IZ)                                                       CM035200
 8013 CHIV(IR)=CHI(IR)                                                    CM035300
 8007 AHR=IHR                                                             CM035400
      AVT=3.0                                                             CM035500
      AVT1=AHR/AVT                                                        CM035600
      IVT1=AVT1                                                           CM035700
      AVT2=AVT1-IVT1                                                      CM035800
      IF(AVT2.GT.0.01) GO TO 8000                                         CM035900
      ISW1=1                                                              CM036000
      DO 8014 IY=1,36                                                   CR036100
      DO 8014 IZ=1,5                                                    CR036200
      IR=SUB(IY,IZ)                                                     CR036300
      CHIH=CHIV(IR)                                                     CR036400
      CHIH=CHIH/AVT                                                     CR036500
      IF(CHIH.LT.HX3(50))GO TO 3304                                     CR036600
      KX3T=(IDY*1000000)+(IR*1000)+IVT1                                 CR036700
      DO 3316 IG=50,2,-1                                                CR036800
      IGJ=IG-1                                                          CR036900
      IF(HX3(IGJ).LT.CHIH)GO TO 3305                                    CR037000
      GO TO 3315                                                        CR037100
 3305 HX3(IG)=HX3(IGJ)                                                  CR037200
 3316 KX3(IG)=KX3(IGJ)                                                  CR037300
      GO TO 3307                                                        CR037400
 3315 HX3(IG)=CHIH                                                      CR037500
      KX3(IG)=KX3T                                                      CR037600
      GO TO 3304                                                        CR037700
 3307 HX3(IGJ)=CHIH                                                     CR037800
      KX3(IGJ)=KX3T                                                     CR037900
 3304 IF(CHIH.LE.CHIVH(IR))GO TO 8019                                   CR038000
      CHIVH2(IR)=CHIVH(IR)                                              CR038100
      CHIVH(IR)=CHIH                                                    CR038200
      JMXD2(IR)=JMXD(IR)                                                CR038300
      JMXD(IR)=IDY                                                      CR038400
      JMXC2(IR)=JMXC(IR)                                                CR038500
      JMXC(IR)=IVT1                                                     CR038600
      GO TO 8014                                                        CR038700
 8019 IF(CHIH.LE.CHIVH2(IR))GO TO 8014                                  CR038800
      CHIVH2(IR)=CHIH                                                   CR038900
      JMXD2(IR)=IDY                                                     CR039000
      JMXC2(IR)=IVT1                                                    CR039100
 8014 CONTINUE                                                          CR039200
 8008 CONTINUE                                                          CR039300
C***COMPUTE AND STORE VARIABLE HOUR VALUES FOR HIGH, SECOND HIGH,       CR039400
C***AND HIGH 50 TABLES                                                  CR039500
      IF(IVT.EQ.0)GO TO 8054                                            CR039600
      IF(ISAV2.EQ.1) GO TO 8050                                         CR039700
      DO 8051 IY=1,36                                                   CR039800
      DO 8051 IZ=1,5                                                    CR039900
      IR=SUB(IY,IZ)                                                     CR040000
 8051 DHIV(IR)=DHIV(IR)+CHI(IR)                                                    CROA0100
      GO TO 8052                                                                   CROA0200
 8050 ISW2=0                                                                       CROA0300
      DO 8053 IY=1,36                                                              CROA0400
      DO 8053 IZ=1,5                                                               CROA0500
      IR=SUB(IY,IZ)                                                                CROA0600
 8053 DHIV(IR)=CHI(IR)                                                             CROA0700
 8052 AHR=IHR                                                                      CROA0800
      AVT=IVT                                                                      CROA0900
      AVT1=AHR/AVT                                                                 CROA1000
      IVT1=AVT1                                                                    CROA1100
      AVT2=AVT1-IVT1                                                               CROA1200
      IF(AVT2.GT.0.01) GO TO 8054                                                  CROA1300
      ISW2=1                                                                       CROA1400
      DO 8055 IY=1,36                                                              CROA1500
      DO 8055 IZ=1,5                                                               CROA1600
      IR=SUB(IY,IZ)                                                                CROA1700
      CHIH=DHIV(IR)                                                                CROA1800
      CHIH=CHIH/AVT                                                                CROA1900
      IF(CHIH.LT.HKK(50))GO TO 3300                                                CROA2000
      KKNT=(IDY*1000000)+(IR*100)+IVT1                                             CROA2100
      DO 3317 IG=50,2,-1                                                           CROA2200
      IGJ=IG-1                                                                     CROA2300
      IF(HKK(IGJ).LT.CHIH)GO TO 3309                                               CROA2400
      GO TO 3313                                                                   CROA2500
 3309 HKK(IG)=HKK(IGJ)                                                             CROA2600
 3317 KKK(IG)=KKK(IGJ)                                                             CROA2700
      GO TO 3314                                                                   CROA2800
 3313 HKK(IG)=CHIH                                                                 CROA2900
      KKK(IG)=KKNT                                                                 CROA3000
      GO TO 3300                                                                   CROA3100
 3314 HKK(IGJ)=CHIH                                                                CROA3200
      KKK(IGJ)=KKNT                                                                CROA3300
 3300 IF(CHIH.LE.DHIVM(IR))GO TO 8056                                              CROA3400
      DHIVM2(IR)=DHIVM(IR)                                                         CROA3500
      DHIVM(IR)=CHIH                                                               CROA3600
      KKKG2(IR)=KKKG(IR)                                                           CROA3700
      KKKG(IR)=IDY                                                                 CROA3800
      KKKC2(IR)=KKKC(IR)                                                           CROA3900
      KKKC(IR)=IVT1                                                                CROA4000
      GO TO 8055                                                        CRD44100
 8054 IF(CHIH.LE.DHIGH2(IR))GO TO 8055                                  CRD44200
      DHIGH2(IR)=CHIH                                                   CRD44300
      KDAY2(IR)=IDY                                                     CRD44400
      KHRS2(IR)=IVT1                                                    CRD44500
 8055 CONTINUE                                                          CRD44600
 8054 CONTINUE                                                          CRD44700
C***END OF 24 HOUR PERIOD                                               CRD44800
      IF(ISC.EQ.0)GO TO 4000                                            CRD44900
C***PRINT SOURCE CONTRIBUTION TABLE.                                    CRD45000
      IF(ISC1(1).EQ.0)GO TO 888                                         CRD45100
C***PRINT HOURLY SOURCE CONTRIBUTIONS                                   CRD45200
      DO 244 ME=1,20                                                    CRD45300
      TOTSC=0.0                                                         CRD45400
  144 FORMAT(50X,'SOURCE CONTRIBUTION TABLE'                            CRD45500
     *10X,'NO. OF SOURCES: ',I2//                                       CRD45600
     *1X,'INT',1X,'DAY',1X,'PER',1X,'R/SR',                             CRD45700
     *2X,'SOURCE 1  SOURCE 2  SOURCE 3  SOURCE 4  ',                    CRD45800
     *'SOURCE 5  SOURCE 6  SOURCE 7  SOURCE 8  SOURCE 9  ',             CRD45900
     *'SOURCE 10     TOTAL')                                            CRD46000
      IF(ISC1(ME).EQ.0)GO TO 244                                        CRD46100
      IF(LINE.EQ.50)WRITE(6,8050)TX1,TX2                                CRD46200
      IF(LINE.EQ.50)WRITE(6,144)NS                                      CRD46300
      IF(NS.GT.10.AND.LINE.EQ.50)WRITE(6,944)                           CRD46400
  944 FORMAT(13X,'SOURCE 11 SOURCE 12 SOURCE 13 SOURCE 14 '             CRD46500
     *,'SOURCE 15 SOURCE 16 SOURCE 17 SOURCE 18 SOURCE 19')             CRD46600
      IF(LINE.EQ.50)WRITE(6,945)                                        CRD46700
  945 FORMAT(6X)                                                        CRD46800
      IF(LINE.EQ.50)LINE=0                                              CRD46900
      LINE=LINE+1                                                       CRD47000
      DO 255 IME=1,NS                                                   CRD47100
  255 TOTSC=CON(ME,IME)+TOTSC                                           CRD47200
      IWORK=ISC1(ME)                                                    CRD47300
      ISCR=SAB(IWORK,1)                                                 CRD47400
      ISCD=SAB(IWORK,2)                                                 CRD47500
      IF(NS.GT.10)GO TO 256                                             CRD47600
      WRITE(6,145)IDY,IHR,ISCR,ISCD,(CON(ME,JAK),JAK=1,10),TOTSC        CRD47700
      GO TO 257                                                         CRD47800
  256 WRITE(6,146)IDY,IHR,ISCR,ISCD,(CON(ME,JAK),JAK=1,10)              CRD47900
  146 FORMAT(2X,'1',2X,I3,2X,I2,1X,I1,'/',I2,1X,10(1PE10.4))            CRD48000
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      WRITE(6,247)(CON2(ME,JAK),JAK=11,19),TOTSC                        CR048100
      LINE=LINE+1                                                       CR048200
  247 FORMAT(10X,9(1PE10.4),12X,1PE10.4)                                CR048300
  257 CONTINUE                                                          CR048400
  245 FORMAT(2X,'1',2X,I3,2X,I2,1X,I1,'/',I2,1X,10(1PE10.4),2X,1PE10.4) CR048500
  244 CONTINUE                                                          CR048600
  266 DO 267 IZZ=1,20                                                   CR048700
      DO 267 JAK=1,19                                                   CR048800
  267 CON2(IZZ,JAK)=0.0                                                 CR048900
  888 IF(ISC3(1).EQ.0)GO TO 788                                         CR049000
C***PRINT 3-HOUR SOURCE CONTRIBUTIONS                                    CR049100
      IPR(2)=IPR(2)+1                                                   CR049200
      IF(IPR(2).NE.3)GO TO 788                                          CR049300
      DO 344 ME=1,20                                                    CR049400
      TOTSC=0.0                                                         CR049500
      IF(ISC3(ME).EQ.0)GO TO 366                                        CR049600
      IF(LINE.EQ.50)WRITE(6,6050)TX1,TX2                                CR049700
      IF(LINE.EQ.50)WRITE(6,244)HS                                      CR049800
      IF(HS.GT.10.AND.LINE.EQ.50)WRITE(6,944)                           CR049900
      IF(LINE.EQ.50)WRITE(6,946)                                        CR050000
      IF(LINE.EQ.50)LINE=0                                              CR050100
      LINE=LINE+1                                                       CR050200
      DO 355 JHE=1,46                                                   CR050300
      CON3(ME,JHE)=CON3(ME,JHE)/3.                                      CR050400
  355 TOTSC=TOTSC+CON3(ME,JHE)                                          CR050500
      IWORK=ISC3(ME)                                                    CR050600
      ISCR=SAB(IWORK,1)                                                 CR050700
      ISCD=SAB(IWORK,2)                                                 CR050800
      ITP=IHR/3                                                         CR050900
      IF(HS.GT.10)GO TO 356                                             CR051000
      WRITE(6,345)IDY,ITP,ISCR,ISCD,(CON3(ME,JAK),JAK=1,10),TOTSC       CR051100
      GO TO 377                                                         CR051200
  356 WRITE(6,378)IDY,ITP,ISCR,ISCD,(CON3(ME,JAK),JAK=1,10)             CR051300
  378 FORMAT(2X,'3',2X,I3,2X,I2,1X,I1,'/',I2,1X,10(1PE10.4))            CR051400
      WRITE(6,247)(CON3(ME,JAK),JAK=11,19),TOTSC                        CR051500
      LINE=LINE+1                                                       CR051600
  377 CONTINUE                                                          CR051700
  345 FORMAT(2X,'3',2X,I3,2X,I2,1X,I1,'/',I2,1X,10(1PE10.4),2X,1PE10.4) CR051800
  344 CONTINUE                                                          CR051900
  366 DO 367 IZZ=1,20                                                   CR052000
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      DO 367 IWW=1,19                                                   CRO52100
  367 CON3(IZZ,IWW)=0.0                                                 CRO52200
      IPR(2)=0                                                          CRO52300
  400 IF(ISCV(1).EQ.0)GO TO 600                                         CRO52400
C***PRINT VARIABLE HOUR SOURCE CONTRIBUTIONS                            CRO52500
      IPR(3)=IPR(3)+1                                                   CRO52600
      IF(IPR(3).NE.IVT)GO TO 600                                        CRO52700
      DO 444 ME=1,20                                                    CRO52800
      TOTSC=0.0                                                         CRO52900
      IF(ISCV(ME).EQ.0)GO TO 666                                        CRO53000
      IF(LINE.EQ.50)WRITE(6,6050)TX1,TX2                                CRO53100
      IF(LINE.EQ.50)WRITE(6,244)NS                                      CRO53200
      IF(NS.GT.10.AND.LINE.EQ.50)WRITE(6,944)                           CRO53300
      IF(LINE.EQ.50)WRITE(6,945)                                        CRO53400
      IF(LINE.EQ.50)LINE=0                                              CRO53500
      LINE=LINE+1                                                       CRO53600
      DO 455 IME=1,NS                                                   CRO53700
      CONV(ME,IME)=CONV(ME,IME)/IVT                                     CRO53800
  455 TOTSC=TOTSC+CONV(ME,IME)                                          CRO53900
      IWORK=ISCV(ME)                                                    CRO54000
      ISCR=SAB(IWORK,1)                                                 CRO54100
      ISCD=SAB(IWORK,2)                                                 CRO54200
      ITP=IHR/IVT                                                       CRO54300
      IF(NS.GT.10)GO TO 721                                             CRO54400
      WRITE(6,445)IVT,IDY,ITP,ISCR,ISCD,(CONV(ME,JAK),JAK=1,10),TOTSC   CRO54500
      GO TO 722                                                         CRO54600
  721 WRITE(6,379)IVT,IDY,ITP,ISCR,ISCD,(CONV(ME,JAK),JAK=1,10)         CRO54700
  379 FORMAT(1X,I2,2X,I3,2X,I2,1X,I1,"/",I2,1X,10(1PE10.4))             CRO54800
      WRITE(6,247)(CONV(ME,JAK),JAK=11,19),TOTSC                        CRO54900
      LINE=LINE+1                                                       CRO55000
  722 CONTINUE                                                          CRO55100
  445 FORMAT(1X,I2,2X,I3,2X,I2,1X,I1,"/",I2,1X,10(1PE10.4),2X,1PE10.4)  CRO55200
  444 CONTINUE                                                          CRO55300
  666 DO 467    IZZ=1,20                                                CRO55400
      DO 467 IWW=1,19                                                   CRO55500
  467 CONV(IZZ,IWW)=0.0                                                 CRO55600
      IPR(3)=0                                                          CRO55700
  600 IF(ISC24(1).EQ.0)GO TO 500                                        CRO55800
C***PRINT 24 HOUR SOURCE CONTRIBUTIONS                                  CRO55900
      IPR(4)=IPR(4)+1                                                   CRO56000
      IF(IPR(4).NE.2)GO TO 588                                          CR056100
      DO 544 ME=1,20                                                    CR056200
      TOTSC=0.0                                                         CR056300
      IF(ISC24(ME).EQ.0)GO TO 566                                       CR056400
      IF(LINE.EQ.50)WRITE(6,6050)TX1,TX2                                CR056500
      IF(LINE.EQ.50)WRITE(6,144)MS                                      CR056600
      IF(MS.GT.10.AND.LINE.EQ.50)WRITE(6,944)                           CR056700
      IF(LINE.EQ.50)WRITE(6,945)                                        CR056800
      IF(LINE.EQ.50)LINE=0                                              CR056900
      LINE=LINE+1                                                       CR057000
      DO 555 IME=1,19                                                   CR057100
      CON24(ME,IME)=CON24(ME,IME)/24.                                   CR057200
  555 TOTSC=TOTSC+CON24(ME,IME)                                         CR057300
      IWORK=ISC24(ME)                                                   CR057400
      ISCR=SAR(IWORK,1)                                                 CR057500
      ISCD=SAR(IWORK,2)                                                 CR057600
      IF(MS.GT.10)GO TO 730                                             CR057700
      WRITE(6,545)IDY,ISCR,ISCD,(CON24(ME,JK),JK=1,10),TOTSC            CR057800
      GO TO 733                                                         CR057900
  730 WRITE(6,380)IDY,ISCR,ISCD,(CON24(ME,JK),JK=1,10)                  CR058000
  380 FORMAT(1X,'24',2X,I3,5X,I1,'/',I2,1X,10(1PE10.4))                 CR058100
      WRITE(6,147)(CON24(ME,JK),JK=11,19),TOTSC                         CR058200
      LINE=LINE+1                                                       CR058300
  733 CONTINUE                                                          CR058400
  545 FORMAT(1X,'24',2X,I3,5X,I1,'/',I2,1X,10(1PE10.4),2X,1PE10.4)      CR058500
  544 CONTINUE                                                          CR058600
  566 DO 567 IZZ=1,20                                                   CR058700
      DO 567 IX=1,19                                                    CR058800
  567 CON24(IZZ,IX)=0.0                                                 CR058900
      IPR(4)=0                                                          CR059000
  588 IF(ISCAN(1).EQ.0)GO TO 1111                                       CR059100
C****PRINT ANNUAL SOURCE CONTRIBUTIONS                                   CR059200
      IPR(5)=IPR(5)+1                                                   CR059300
      IF(IPR(5).NE.IHRAN)GO TO 1111                                     CR059400
      DO 744 ME=1,20                                                    CR059500
      TOTSC=0.0                                                         CR059600
      IF(ISCAN(ME).EQ.0)GO TO 766                                       CR059700
      IF(LINE.EQ.50)WRITE(6,6050)TX1,TX2                                CR059800
      IF(LINE.EQ.50)WRITE(6,144)MS                                      CR059900
      IF(MS.GT.10.AND.LINE.EQ.50)WRITE(6,944)                           CR060000
      IF(LINE.EQ.50)WRITE(6,945)                                        CP060100
      IF(LINE.EQ.50)LINE=0                                              CP060200
      LINE=LINE+1                                                       CP060300
      DO 755 JME=1,46                                                   CP060400
      CONAV(ME,JME)=CONAV(ME,JME)/DAHAN                                 CP060500
  755 TOTSC=TOTSC+CONAV(ME,JME)                                         CP060600
      IWORK=ISCAN(ME)                                                   CP060700
      ISCR=SAB(IWORK,1)                                                 CP060800
      ISCD=SAB(IWORK,2)                                                 CP060900
      IF(NS.GT.10)GO TO 740                                             CP061000
      WRITE(6,745)ISCR,ISCD,(CONAV(ME,JAK),JAK=1,10),TOTSC              CP061100
      GO TO 750                                                         CP061200
  740 WRITE(6,305)ISCR,ISCD,(CONAV(ME,JAK),JAK=1,10)                    CP061300
  305 FORMAT(1X,'RN',10X,I1,'/'I2,1X,10(1PE10.4))                       CP061400
      WRITE(6,347)(CONAV(ME,JAK),JAK=11,29),TOTSC                       CP061500
      LINE=LINE+1                                                       CP061600
  750 CONTINUE                                                          CP061700
  745 FORMAT(1X,'RN',10X,I1,'/'I2,1X,10(1PE10.4),2X,1PE10.4)            CP061800
  744 CONTINUE                                                          CP061900
  766 CONTINUE                                                          CP062000
 1111 CONTINUE                                                          CP062100
C***PRINTING OF SOURCE CONTRIBUTIONS COMPLETED                          CP062200
C***WRITE OUTPUT TAPE: 1 RECORD OF 180 HOURLY CONCENTRATIONS            CP062300
 4000 IF(ITAP.NE.1)GO TO 4001                                           CP062400
      WRITE(8)STAPE1                                                    CP062500
 4001 CONTINUE                                                          CP062600
      IF(ISC.EQ.1)GO TO 5000                                            CP062700
C***OUTPUT HOURLY CONCENTRATIONS FOR THIS DAY                           CP062800
C***CALCULATE 24-HOUR AVERAGES FOR EACH RECEPTOR                        CP062900
      IF(ICALC.NE.0)GO TO 4640                                          CP063000
      WRITE(6,4651)IDY                                                  CP063100
 4651 FORMAT(' DAY---',I3,'   NO CALCULATIONS PERFORMED--NO DIRECTIONS SECP063200
     *LECTED'/)                                                         CP063300
      GO TO 4001                                                        CP063400
 4640 CONTINUE                                                          CP063500
C***COMPUTE AND STORE 24-HOUR VALUES FOR HIGH AND SECOND HIGH TABLES    CP063600
      DO 4634 IDIR=1,36                                                 CP063700
      DO 4635 LJ=1,5                                                    CP063800
      IP=SUB(IDIR,LJ)                                                   CP063900
      CHI=CHI25(IP)/24.                                                 CP064000
      CH25(IR)=CH                                                       CP064100
      IF(CH.LE.DMAXT)GO TO 8000                                         CP064200
      DMAXT=CH                                                          CP064300
      NNN=IR                                                            CP064400
 8000 IF(CH.LE.DMAX1(IR))GO TO 8001                                     CP064500
      DMAX2(IR)=DMAX1(IR)                                               CP064600
      DMAX1(IR)=CH                                                      CP064700
      JMAX2(IR)=JMAX1(IR)                                               CP064800
      JMAX1(IR)=IDY                                                     CP064900
      GO TO 4435                                                        CP065000
 8001 IF(CH.LE.DMAX2(IR))GO TO 4435                                     CP065100
      DMAX2(IR)=CH                                                      CP065200
      JMAX2(IR)=IDY                                                     CP065300
 4435 CH26(IR)=CH26(IR)+CH                                              CP065400
 4635 CONTINUE                                                          CP065500
 4634 CONTINUE                                                          CP065600
      RATIO=DMAXT/CMAXT                                                 CP065700
C***OUTPUT DAILY CONCENTRATIONS                                         CP065800
      IF(IMET.EQ.0)GO TO 4652                                           CP065900
      WRITE(6,4650)                                                     CP066000
 4650 FORMAT(47X,"M A X   H O U R L Y",                                 CP066100
     *25X,"M A X   2 4 - H O U R"//26X,"     DAY       RATIO     CONCENTRCP066200
     *ATION  DIRECTION  DISTANCE(KM)  HOUR    CONCENTRATION  DIRECTION  CP066300
     *DISTANCE(KM)")                                                    CP066400
      GO TO 4653                                                        CP066500
 4652 IF (IFIR.EQ.0)WRITE(6,6050)TX1,TX2                                CP066600
      IF(IFIR.EQ.0)WRITE(6,4654)                                        CP066700
 4654 FORMAT(46X,"M A X   H O U R L Y",                                 CP066800
     *25X,"M A X   2 4 - H O U R"//                                     CP066900
     *8X,"DAY        RATIO     CO"                                      CP067000
     *"NCENTRATION  DIRECTION  DISTANCE(KM)  HOUR    CONCENTRATION  DIRECP067100
     *CTION  DISTANCE(KM)")                                             CP067200
      TXDY=IDY/50.                                                      CP067300
      ITXDY=TXDY                                                        CP067400
      TXDZ=TXDY-ITXDY                                                   CP067500
      IF(TXDZ.LT.0.01)WRITE(6,6050)TX1,TX2                              CP067600
      IF(TXDZ.LT.0.01)WRITE(6,4654)                                     CP067700
      IFIR=1                                                            CP067800
 4653 DDD(IDY)=DMAXT                                                    CP067900
      KDD(IDY)=NNN                                                      CP068000
      MMMM=NNNN                                                         CP068100
      AJD=SAB(MMMM,1)                                                   CP068200
      MMMM=MMM(1)                                                       CP068300
      AID=SAB(MMMM,2)                                                   CP068400
      AJH=SAB(MMMM,1)                                                   CP068500
      AIH=SAB(MMMM,2)                                                   CP068600
      MMMM=MMM(2)                                                       CP068700
      ISTI=1                                                            CP068800
      KI=1                                                              CP068900
      IF(IMET.EQ.0)GO TO 4799                                           CP069000
      WRITE(6,4730)IDY,RATIO,HMAXT,KJH,                                 CP069100
     *RNG(AJH),KH,DMAXT,KID,RNG(AID)                                    CP069200
 4730 FORMAT(8X,I3,1X,F11.3,1PE17.6,I7,0PF14.2,I9,1PE18.6,I7,           CP069300
     *0PF14.2)                                                          CP069400
      GO TO 4800                                                        CP069500
 4799 WRITE(6,4731)IDY,RATIO,HMAXT,KJH,                                 CP069600
     *RNG(AJH),KH,DMAXT,KID,RNG(AID)                                    CP069700
 4731 FORMAT(8X,I3,1X,F11.3,1PE17.6,I7,0PF14.2,I9,1PE18.6,I7,           CP069800
     *0PF14.2)                                                          CP069900
 4800 IF(DMAXT.LE.DMAXYR(1))GO TO 4900                                  CP070000
      DMAXYR(1)=DMAXT                                                   CP070100
      DMAXYR(3)=RNG(AID)                                                CP070200
      JMAX3(2)=KID                                                      CP070300
      JMAX3(4)=IDY                                                      CP070400
 4900 CONTINUE                                                          CP070500
C***WRITE OUTPUT TAPE: 1 RECORD OF 180 24-HOUR CONCENTRATIONS***        CP070600
 4901 IF(ITAP.NE.1)GO TO 5000                                           CP070700
      WRITE(8)GTAPE2                                                    CP070800
C***END DAILY LOOP***                                                   CP070900
 5000 CONTINUE                                                          CP071000
      IF(ISC.EQ.1) STOP                                                 CP071100
C***CALCULATE ANNUAL MEANS AND DETERMINE THE MAXIMA*                    CP071200
      ISTI=1                                                            CP071300
      KI=1                                                              CP071400
      AMAX=0.                                                           CP071500
      MAXI=0                                                            CP071600
      DO 5200 IR=1,180                                                  CP071700
      CH=CH26(IR)/TDAY                                                  CP071800
      CH26(IR)=CH                                                       CP071900
      IF(CH.LE.AMAX)GO TO 5200                                          CP072000
      AMAXC=C                                                           CR072100
      MAXI=IR                                                           CR072200
 5200 CONTINUE                                                          CR072300
C***PRINT MAXIMUM ANNUAL MEAN                                           CR072400
      WRITE(6,6050) TX1,TX2                                             CR072500
 6050 FORMAT(1H1,2X,'PLANT NAME: ',6A4,'  POLLUTANT: ',2A4,             CR072600
     *'  EMISSION UNITS: GM/SEC  ','  AIR QUALITY UNITS: GM/M**3'/)     CR072700
      MAX1=SAR(MAXI,1)                                                  CR072800
      MAX2=SAR(MAXI,2)                                                  CR072900
      WRITE(6,6100)AMAXC,MAX2,AMG(MAXI)                                 CR073000
 6100 FORMAT(1X,T4,'      MAXIMUM MEAN CONC=',1PE12.4,'  DIRECTION=',   CR073100
     *I3,'  DISTANCE=',0PF5.1,' KM'//1X)                                CR073200
C***PRINT ANNUAL MEANS***                                               CR073300
      WRITE(6,6200) RHS                                                 CR073400
 6200 FORMAT(1X,      /1X,T21,'ANNUAL MEAN CONCENTRATION AT EACH RECEPTOCR073500
     *OR'/1X,T7,'RANGE',2X,5(F5.1,' KM'),T61/1X,T2,'DIR'),              CR073600
      LJ=0                                                              CR073700
      DO 6799 LEP=1,36                                                  CR073800
      DO 6799 LES =1,5                                                  CR073900
      LJ=LJ+1                                                           CR074000
      LA=SAR(LEP,LES)                                                   CR074100
      DMAX1(LJ)=DMAX1(LA)                                               CR074200
      JMAX1(LJ)=JMAX1(LA)                                               CR074300
      CHIAV1(LJ)=CHIBR(LA)                                              CR074400
 6799 CONTINUE                                                          CR074500
      DO 6301 I=1,36                                                    CR074600
      IFR=I*5-4                                                         CR074700
      ITO=I*5                                                           CR074800
      WRITE(6,6300)I,(CHIAV1(J),J=IFR,ITO)                              CR074900
 6301 CONTINUE                                                          CR075000
 6300 FORMAT(1X,T3,I2,T10,1P5E15.5)                                     CR075100
C***PRINT HIGHEST 24-HOUR CONCENTRATION FOR THE YEAR AT EACH RECEPTOR   CR075200
      WRITE(6,6050) TX1,TX2                                             CR075300
      WRITE(6,7050)(CHMAX(L),L=1,4)                                     CR075400
 7050 FORMAT(1X,'YEARLY MAXIMUM 24-HOUR CONC=',1PE12.4,'  DIRECTION=',  CR075500
     *I4,'  DISTANCE=',0PF5.1,' KM  DAY=',I3/)                          CR075600
      WRITE(6,7150)RHS                                                  CR075700
 7150 FORMAT(1X,      /1X,T17,'HIGHEST 24-HOUR CONCENTRATION AT EACH RECR075800
     *CEPTOR'/1X,T4,'RANGE   ',5(F5.1,' KM'),T44/1X,T2,'DIR')           CR075900
      DO 7401 I=1,36                                                    CR076000
      IFR=I*5-4                                                         CRST6100
      ITO=I*5                                                           CRST6200
      WRITE(6,7400)I,(DMAXUM(I,J),JMAXU1(I,J),J=IFR,ITO)                CRST6300
 7401 CONTINUE                                                          CRST6400
 7400 FORMAT(1X,T3,I2,T6,5(1PE11.4,' (',I3,')',5X))                     CRST6500
 8040 FORMAT(1X,T3,I2,T6,5(1PE11.4,' (',I3,',',I2,')',5X))              CRST6600
C***PRINT SECOND HIGHEST 24-HOUR CONCENTRATIONS FOR THE YEAR AT          CRST6700
C***EACH RECEPTOR                                                       [illegible]
      IJK=0                                                             [illegible]
      DX(1)=0.0                                                         CRST7000
      DO 3002 IJER=1,36                                                 CRST7100
      DO 3002 IJES =1,5                                                 CRST7200
      IJK=IJK+1                                                         CRST7300
      IJK=ISUB(IJER,IJES)                                               CRST7400
      IF(DMAX2(IJK).LE.DX(1))GO TO 8005                                 CRST7500
      DX(1)=DMAX2(IJK)                                                  CRST7600
      JX(2)=IJER                                                        CRST7700
      DX(3)=RNG(IJES)                                                   CRST7800
      JX(4)=JMAX12(IJK)                                                 CRST7900
 8005 DMAXUM(IJK)=DMAX2(IJK)                                            CRST8000
      JMAXU1(IJK)=JMAX12(IJK)                                           CRST8100
 3002 CONTINUE                                                          CRST8200
      WRITE(6,6050) TX1,TX2                                             CRST8300
      WRITE(6,8021)(DX(L),L=1,4)                                        CRST8400
 8021 FORMAT(1X,'YEARLY SECOND MAXIMUM 24-HOUR CONC=',1PE12.4,          CRST8500
     *'  DIRECTION=',I4,'  DISTANCE=',0PF5.1,' KM  DAY=',I3/)           CRST8600
      WRITE(6,8009)RNG                                                  CRST8700
 8009 FORMAT(1X,/1X,T17,'SECOND HIGHEST 24-HOUR CONCENTRATION AT EACH RECRST8800
     *CEPTOR'/1X,T4,'RANGE    ',5(F5.1,' KM',14X)/1X,T2,'DIR')          CRST8900
      DO 8003 I=1,36                                                    CRST9000
      IFR=I*5-4                                                         CRST9100
      ITO=I*5                                                           CRST9200
      WRITE(6,7400)I,(DMAXUM(I,J),JMAXU1(I,J),J=IFR,ITO)                CRST9300
 8003 CONTINUE                                                          CRST9400
      IF(IVT.EQ.0)GO TO 8045                                            CRST9500
C***PRINT HIGHEST VARIABLE HOUR CONCENTRATIONS FOR THE YEAR AT          CRST9600
C***EACH RECEPTOR                                                       CRST9700
      IJK=0                                                             [illegible]
      DX(1)=0.0                                                         [illegible]
      DO 8057 IJER=1,36                                                 [illegible]
      DO 8057 IJES =1,5                                                 CR080100
      IJK=IJK+1                                                         CR080200
      IJK=SUB(IJEP,IJES)                                                CR080300
      IF(CHIMAX(IJK).LE.DX(1))GO TO 8056                                CR080400
      DX(1)=CHIMAX(IJK)                                                 CR080500
      JX(2)=IJEP                                                        CR080600
      DX(3)=RNG(IJES)                                                   CR080700
      JX(4)=JMAXD(IJK)                                                  CR080800
      JX(5)=JMAXC(IJK)                                                  CR080900
 8056 CHMAXV(IJK)=CHIMAX(IJK)                                           CR081000
      JMAXD1(IJK)=JMAXD(IJK)                                            CR081100
      IJMX(IJK)=JMAXC(IJK)                                              CR081200
 8057 CONTINUE                                                          CR081300
      WRITE(6,6050) TX1,TX2                                             CR081400
      WRITE(6,8059)IVT,(DX(L),L=1,5)                                    CR081500
 8059 FORMAT(1X,'YEARLY MAXIMUM ',I2,'-HOUR CONC=',1PE12.4,             CR081600
     *'  DIRECTION=',I4,'  DISTANCE=',0PF5.1,' KM  DAY=',I3,            CR081700
     *'    TIME PERIOD=',I2/)                                           CR081800
      WRITE(6,8060)IVT,RNG                                              CR081900
 8060 FORMAT(1X,       /1X,T17,'HIGHEST ',I2,'-HOUR CONCENTRATION AT EACCR082000
     ** RECEPTOR'/1X,T4,'RANGE    ',4(F5.1,' KM',I7X),F5.1,' KM'/1X,T2,  CR082100
     *'DIR')                                                            CR082200
      DO 8061 I=1,36                                                    CR082300
      IFR=I*5-4                                                         CR082400
      ITO=I*5                                                           CR082500
      WRITE(6,8040)I,(CHMAXV(I,J),JMAXD1(I,J),IJMX(I,J),J=IFR,ITO)      CR082600
 8061 CONTINUE                                                          CR082700
C***PRINT SECOND HIGHEST VARIABLE HOUR CONCENTRATIONS FOR THE YEAR AT   CR082800
C***EACH RECEPTOR                                                       CR082900
      IJK=0                                                             CR083000
      DX(1)=0.0                                                         CR083100
      DO 8062 IJEP=1,36                                                 CR083200
      DO 8062 IJES =1,5                                                 CR083300
      IJK=IJK+1                                                         CR083400
      IJK=SUB(IJEP,IJES)                                                CR083500
      IF(CHIMX2(IJK).LE.DX(1))GO TO 8063                                CR083600
      DX(1)=CHIMX2(IJK)                                                 CR083700
      JX(2)=IJEP                                                        CR083800
      DX(3)=RNG(IJES)                                                   CR083900
      JX(4)=JMAXD2(IJK)                                                 CR084000
      JM(5)=JMVC2(IK)                                                   CR084100
 0063 DMAXU(IK)=CHIVM2(IK)                                              CR084200
      JMAX1(IK)=JMVD2(IK)                                               CR084300
      IUVC(IK)=JMVC2(IK)                                                CR084400
 0062 CONTINUE                                                          CR084500
      WRITE(6,6050) TX1,TX2                                             CR084600
      WRITE(6,8064)IVT,(DX(L),L=1,5)                                    CR084700
 8064 FORMAT(1X,'YEARLY SECOND MAXIMUM ',I2,'-HOUR CONC=',1PE12.4,      CR084800
     *'  DIRECTION=',I4,'  DISTANCE=',0PF5.1,' KM  DAY=',I3,            CR084900
     *'     TIME PERIOD=',I2/)                                          CR085000
      WRITE(6,8065)IVT,RNG                                              CR085100
 8065 FORMAT(1X,/1X,T17,'SECOND HIGHEST ',I2,'-HOUR CONCENTRATION AT EACCR085200
     *H RECEPTOR'/1X,T4,'RANGE    ',4(F5.1,' KM',17X),F5.1,' KM'/1X,T2, CR085300
     *'DIR')                                                            CR085400
      DO 8066 I=1,36                                                    CR085500
      IFR=I*5-4                                                         CR085600
      ITO=I*5                                                           CR085700
      WRITE(6,8048)I,(DMAXU(J),JMAX1(J),IUVC(J),J=IFR,ITO)              CR085800
 8066 CONTINUE                                                          CR085900
C***PRINT HIGHEST 3-HOUR CONCENTRATIONS FOR THE YEAR AT EACH RECEPTOR    CR086000
 8045 IK=0                                                              CR086100
      DX(1)=0.0                                                         CR086200
      DO 8015 IEP=1,36                                                  CR086300
      DO 8015 IES =1,5                                                  CR086400
      IK=IK+1                                                           CR086500
      IK=ISUB(IEP,IES)                                                  CR086600
      IF(CHIVM(IK).LE.DX(1))GO TO 8010                                  CR086700
      DX(1)=CHIVM(IK)                                                   CR086800
      JM(2)=IEP                                                         CR086900
      DX(3)=RNG(IES)                                                    CR087000
      JM(4)=JMVD(IK)                                                    CR087100
      JM(5)=JMVC(IK)                                                    CR087200
 8010 DMAXU(IK)=CHIVM(IK)                                               CR087300
      JMAX1(IK)=JMVD(IK)                                                CR087400
      IUVC(IK)=JMVC(IK)                                                 CR087500
 8015 CONTINUE                                                          CR087600
      WRITE(6,6050) TX1,TX2                                             CR087700
      WRITE(6,8022)(DX(L),L=1,5)                                        CR087800
 8022 FORMAT(1X,'YEARLY MAXIMUM       3-HOUR CONC=',1PE12.4,            CR087900
     *'  DIRECTION=',I4,'  DISTANCE=',0PF5.1,' KM  DAY=',I3,            CR088000
     *'   -TIME PERIOD=',I2/)                                          CR088100
      WRITE(6,8029)RNG                                                 CR088200
 8029 FORMAT(1X,       /1X,T17,'HIGHEST      3-HOUR CONCENTRATION AT EACCR088300
     *, RECEPTOR'/1X,T4,'RANGE    ',4(F5.1,' KM',17X),F5.1,' KM'/1X,T2, CR088400
     *'DIR')                                                           CR088500
      DO 8016 I=1,36                                                   CR088600
      IFR=I*5-4                                                        CR088700
      ITO=I*5                                                          CR088800
      WRITE(6,8040)(I,(CMAXM(LJ),JMAXD(LJ),IHX(LJ),LJ=IFR,ITO))       CR088900
 8016 CONTINUE                                                         CR089000
C***PRINT SECOND HIGHEST 3-HOUR CONCENTRATIONS FOR THE YEAR AT          CR089100
C***EACH RECEPTOR                                                      CR089200
      IJA=0                                                            CR089300
      DX(1)=0.0                                                        CR089400
      DO 8023 IJER=1,36                                                CR089500
      DO 8023 IJES =1,5                                                CR089600
      IJA=IJA+1                                                        CR089700
      IJK=SJ(IJER,IJES)                                                CR089800
      IF(CHIMX2(IJK).LE.DX(1))GO TO 8030                               CR089900
      DX(1)=CHIMX2(IJK)                                                CR090000
      JX(2)=IJER                                                       CR090100
      DX(3)=RNG(IJES)                                                  CR090200
      JX(4)=JMX2(IJK)                                                  CR090300
      JX(5)=JHX2(IJK)                                                  CR090400
 8030 CMAXM(IJA)=CHIMX2(IJK)                                           CR090500
      JMAXD(IJA)=JMX2(IJK)                                             CR090600
      IHX(IJA)=JHX2(IJK)                                               CR090700
 8023 CONTINUE                                                         CR090800
      WRITE(6,8050) TX1,TX2                                            CR090900
      WRITE(6,8025)(DX(L),L=1,5)                                       CR091000
 8025 FORMAT(1X,'YEARLY SECOND MAXIMUM      3-HOUR CONC=',1PE12.4,      CR091100
     *'  DIRECTION=',I4,'  DISTANCE=',0PF5.1,' KM  DAY=',I3,           CR091200
     *'     TIME PERIOD=',I2/)                                         CR091300
      WRITE(6,8033)RNG                                                 CR091400
 8033 FORMAT(1X,/1X,T17,'SECOND HIGHEST      3-HOUR CONCENTRATION AT EACCR091500
     *, RECEPTOR'/1X,T4,'RANGE    ',4(F5.1,' KM',17X),F5.1,' KM'/1X,T2, CR091600
     *'DIR')                                                           CR091700
      DO 8024 I=1,36                                                   CR091800
      IFR=I*5-4                                                        CR091900
      ITO=I*5                                                          CR092000
      WRITE(6,8040)(I,CMAX1(L,J),JMAX1(L,J),IHD1(L,J),J=IFR,ITO)        CR092100
 8014 CONTINUE                                                          CR092200
C***PRINT HIGHEST 1-HOUR CONCENTRATIONS FOR THE YEAR AT EACH RECEPTOR   CR092300
      IJX=0                                                             CR092400
      DX(1)=0.0                                                         CR092500
      DO 8017 IEP=1,36                                                  CR092600
      DO 8017 IES =1,5                                                  CR092700
      IJX=IJX+1                                                         CR092800
      IAX=ISB(IEP,IES)                                                  CR092900
      IF(CHI4(IAX).LE.DX(1))GO TO 8016                                  CR093000
      DX(1)=CHI4(IAX)                                                   CR093100
      JX(2)=IEP                                                         CR093200
      DX(3)=RNG(IES)                                                    CR093300
      JX(4)=JMHD(IAX)                                                   CR093400
      JX(5)=JMHH(IAX)                                                   CR093500
 8016 CMAX1(IJX)=CHI4(IAX)                                              CR093600
      JMAX1(IJX)=JMHD(IAX)                                              CR093700
      IHD1(IJX)=JMHH(IAX)                                               CR093800
 8017 CONTINUE                                                          CR093900
      WRITE(6,8050) TX1,TX2                                             CR094000
      WRITE(6,8032)(DX(L),L=1,5)                                        CR094100
 8032 FORMAT(1X,'YEARLY MAXIMUM 1-HOUR CONC=',1PE12.4,                  CR094200
     *' DIRECTION=',I4,' DISTANCE=',0PF5.1,' KM  DAY=',I3,              CR094300
     *'   HOUR=',I2/)                                                   CR094400
      WRITE(6,8035)RNG                                                  CR094500
 8035 FORMAT(1X,        /1X,T17,'HIGHEST  1-HOUR CONCENTRATION AT EACH RECR094600
     *CEPTOR'/1X,T4,'AL IF   ',4(F5.1,' KM',I7X),F5.1,' KM'/1X,T2,'DIR'CR094700
      DO 8018 I=1,36                                                    CR094800
      IFR=I*5-4                                                         CR094900
      ITO=I*5                                                           CR095000
      WRITE(6,8040)(I,CMAX1(L,J),JMAX1(L,J),IHD1(L,J),J=IFR,ITO)        CR095100
 8018 CONTINUE                                                          CR095200
C***PRINT SECOND HIGHEST 1-HOUR CONCENTRATIONS FOR THE YEAR AT          CR095300
C***EACH RECEPTOR                                                       CR095400
      IJX=0                                                             CR095500
      DX(1)=0.0                                                         CR095600
      DO 8026 IEP=1,36                                                  CR095700
      DO 8026 IES =1,5                                                  CR095800
      IJX=IJX+1                                                         CR095900
      IAX=ISB(IEP,IES)                                                  CR096000
      IF(CH24H2(I,K).LE.DX(1))GO TO 9036                                CR096100
      DX(1)=CH24H2(I,K)                                                 CR096200
      JX(2)=ILEP                                                        CR096300
      DX(3)=DHG(ILES)                                                   CR096400
      JX(4)=JH42(I,K)                                                   CR096500
      JX(5)=JHH42(I,K)                                                  CR096600
 9036 DMAXH(I,K)=CH24H2(I,K)                                            CR096700
      JMAXD(I,K)=JH42(I,K)                                              CR096800
      IUAD(I,K)=JHH42(I,K)                                              CR096900
 9026 CONTINUE                                                          CR097000
      WRITE(6,6050) TX1,TX2                                             CR097100
      WRITE(6,9028)(DX(L),L=1,6)                                        CR097200
 9028 FORMAT(1X,'YEARLY SECOND MAXIMUM 1-HOUR CONC=',1PE12.4,           CR097300
     &'  DIRECTION=',I4,'  DISTANCE=',0PF5.1,' KM   DAY=',I3,           CR097400
     &'    HOUR=',I2/)                                                  CR097500
      WRITE(6,9037)RNG                                                  CR097600
 9037 FORMAT(1X,/1X,T17,'SECOND HIGHEST  1-HOUR CONCENTRATION AT EACH RECCR097700
     &EPTOR'/1X,T4,'RANGE     ',4(F5.1,' KM',I7X),F5.1,' KM'/1X,T2,'DIR')CR097800
      DO 9027 I=1,36                                                    CR097900
      IFR=I*5-4                                                         CR098000
      ITH=I*5                                                           CR098100
      WRITE(6,8040)(I,(HMAX2(I,J),JMAX2(I,J),IUAD(I,J),J=IFR,ITH))      CR098200
 9027 CONTINUE                                                          CR098300
C***DETERMINE HIGH 50 24-HOUR CONCENTRATIONS AND PRINT                  CR098400
      DO 9004 I=1,50                                                    CR098500
      JJ=I+1                                                            CR098600
      DO 9004 J=JJ,366                                                  CR098700
      IF(DDD(I).GT.DDD(J))GO TO 9004                                    CR098800
      DX=DDD(I)                                                         CR098900
      DDD(I)=DDD(J)                                                     CR099000
      DDD(J)=DX                                                         CR099100
      JX=JDD(I)                                                         CR099200
      JDD(I)=JDD(J)                                                     CR099300
      JDD(J)=JX                                                         CR099400
      KX=KDD(I)                                                         CR099500
      KDD(I)=KDD(J)                                                     CR099600
      KDD(J)=KX                                                         CR099700
 9004 CONTINUE                                                          CR099800
      WRITE(6,6050) TX1,TX2                                             CR099900
      WRITE(6,9005)                                                     CR100000
 4005 FORMAT(51X,'MAXIMUM DAILY CONCENTRATIONS'//40X,                   CR100100
     *'DAY    24-HOUR CONCENTRATION    DIRECTION    DISTANCE'/)         CR100200
      DO 9006 I=1,50                                                    CR100300
      IF(DID(I).LE.0.)GO TO 3350                                        CR100400
      KDID=KD(I)                                                        CR100500
      KJD=SAB(KDID,1)                                                   CR100600
      KID=SAB(KDID,2)                                                   CR100700
 9006 WRITE(6,9008)JDD(I),DDD(I),KID,RNG(KJD)                           CR100800
 9008 FORMAT(40X,I3,1PE20.4,I14,0PF14.2)                                CR100900
C***PRINT HIGH 50 VARIABLE HOUR CONCENTRATIONS                          CR101000
 3350 IF(IHT.EQ.0)GO TO 3324                                            CR101100
      WRITE(6,6050) TX1,TX2                                             CR101200
      WRITE(6,3319)IHT,IHT                                              CR101300
 3319 FORMAT(61X,'MAXIMUM ',I2,'-HOURLY CONCENTRATIONS'//40X,           CR101400
     *'DAY     ',I2,'-HOUR CONCENTRATION    DIRECTION    DISTANCE',     CR101500
     *'    TIME PERIOD'/)                                               CR101600
      DO 3318 I=1,50                                                    CR101700
      IF(HVX(I).LE.0.)GO TO 3351                                        CR101800
      KR1=HVY(I)                                                        CR101900
      KR2=KR1+0.00001                                                   CR102000
      KR3=KR2*100000                                                    CR102100
      KR4=KR1-KR3                                                       CR102200
      KR5=KR4+0.01                                                      CR102300
      KR6=KR5*100                                                       CR102400
      KR7=KR4-KR6                                                       CR102500
      KA4=SAB(KR5,1)                                                    CR102600
      SP5=RNG(KA4)                                                      CR102700
      KA4=SAB(KR5,2)                                                    CR102800
 3318 WRITE(6,3320)KR2,HVX(I),KA4,SP5,KR7                               CR102900
 3320 FORMAT(40X,I3,1PE20.4,I14,0PF14.2,I11,I3)                         CR103000
 3324 CONTINUE                                                          CR103100
C***PRINT HIGH 50 3-HOUR CONCENTRATIONS                                 CR103200
 3351 WRITE(6,6050) TX1,TX2                                             CR103300
      WRITE(6,3322)                                                     CR103400
 3322 FORMAT(61X,'MAXIMUM 3-HOURLY CONCENTRATIONS'//40X,                CR103500
     *'DAY     3-HOUR CONCENTRATION    DIRECTION    DISTANCE',          CR103600
     *'    TIME PERIOD'/)                                               CR103700
      DO 3321 I=1,50                                                    CR103800
      IF(H3(I).LE.0.)GO TO 3352                                         CR103900
      KR1=H3(I)                                                         CR104000
      XR2=XR1*0.00001                                                   CP104100
      XR3=XR2*100000                                                    CP104200
      XR4=XR1-XR3                                                       CP104300
      XR5=XR4*0.01                                                      CP104400
      KR6=XR5*100                                                       CP104500
      XR7=XR4-KR6                                                       CP104600
      KRAS=SAB(KR5+1)                                                   CP104700
      SP5=PHI(KRA)                                                      CP104800
      KRAS=SAB(KR5+2)                                                   CP104900
 3321 WRITE(6,3323)XR2,XA3(I),KRA,SP5,XR7                               CP105000
 3323 FORMAT(40X,I3,1PE20.4,I14,0PF14.2,11X,I3)                         CP105100
C***PRINT HIGH 50 1-HOUR CONCENTRATIONS                                 CP105200
 3352 WRITE(6,6850) TX1,TX2                                             CP105300
      WRITE(6,3311)                                                     CP105400
 3311 FORMAT(61X,"MAXIMUM HOURLY CONCENTRATIONS"//40X,                  CP105500
     *"DAY     1-HOUR CONCENTRATION     DIRECTION     DISTANCE",        CP105600
     *"     HOUR"/)                                                     CP105700
      DO 3310 I=1,50                                                    CP105800
      IF(XA1(I).LE.0.)GO TO 4007                                        CP105900
      XR1=XA1(I)                                                        CP106000
      XR2=XR1*0.00001                                                   CP106100
      XR3=XR2*100000                                                    CP106200
      XR4=XR1-XR3                                                       CP106300
      XR5=XR4*0.01                                                      CP106400
      KR6=XR5*100                                                       CP106500
      XR7=XR4-KR6                                                       CP106600
      KRAS=SAB(KR5+1)                                                   CP106700
      SP5=PHI(KRA)                                                      CP106800
      KRAS=SAB(KR5+2)                                                   CP106900
 3310 WRITE(6,3312)XR2,XA1(I),KRA,SP5,XR7                               CP107000
 3312 FORMAT(40X,I3,1PE20.4,I14,0PF14.2,7X,I3)                          CP107100
C***WRITE OUTPUT TAPE: 1 RECORD OF 100 YEAR ANNUAL CONCENTRATIONS       CP107200
 4007 IF(ITAP.NE.1)RETURN                                               CP107300
      WRITE(8)XTAPE3                                                    CP107400
      END FILE 8                                                        CP107500
      RETURN                                                            CP107600
      END                                                               CP107700
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SINGLE SOURCE (CRSTER) MODEL - SUBROUTINE SIGMA

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      SUBROUTINE SIGMA (X,XY,KST,SY,SZ)                                 SIG00100
C     SUBROUTINE SIGMA CALCULATES HORIZONTAL AND VERTICAL STANDARD      SIG00200
C       DEVIATIONS OF CONCENTRATION.  THE HORIZONTAL STD. DEV., SY IS   SIG00300
C       OBTAINED FROM THE ANGLE BETWEEN A LINE DRAWN FROM THE SOURCE    SIG00400
C       IN THE DOWNWIND DIRECTION AND THE BOUNDARY OF THE PLUME AS IS   SIG00500
C       SUGGESTED BY PASQUILL.  PASQUILL'S DISCUSSION ACTUALLY USES     SIG00600
C       TWO TIMES THIS ANGLE.  THE VERTICAL STD. DEV., SZ, IS           SIG00700
C       CALCULATED FROM A SET OF EQUATIONS DEPENDENT UPON STABILITY     SIG00800
C       CLASS AND DOWNWIND DISTANCE OF THE RECEPTOR.                    SIG00900
C     THE VARIABLES USED IN SUBROUTINE SIGMA ARE....                    SIG01000
C       X    DISTANCE RECEPTOR IS DOWNWIND OF SOURCE (KM)               SIG01100
C       XY   X+VIRTUAL DISTANCE USED FOR AREA SOURCE APPROX. (KM)       SIG01200
C       KST  STABILITY CLASS, SEE PAGE 209 OF PASQUILL, ATMOSPHERIC     SIG01300
C              DISPERSION                                               SIG01400
C               1  IS PASQUILL STABILITY CLASS A                        SIG01500
C               2  IS PASQUILL STABILITY CLASS B                        SIG01600
C               3  IS PASQUILL STABILITY CLASS C                        SIG01700
C               4  IS PASQUILL STABILITY CLASS D2                       SIG01800
C               5  IS PASQUILL STABILITY CLASS E                        SIG01900
C               6  IS PASQUILL STABILITY CLASS F                        SIG02000
C               7  IS PASQUILL STABILITY CLASS D1                       SIG02100
C              41  IS PASQUILL STABILITY CLASS D1                       SIG02200
C              42  IS PASQUILL STABILITY CLASS D2                       SIG02300
C       SY   SIGMA Y, THE STANDARD DEVIATION OF CONCENTRATION IN THE    SIG02400
C              Y-DIRECTION (M)                                          SIG02500
C       SZ   SIGMA Z, THE STANDARD DEVIATION OF CONCENTRATION IN THE    SIG02600
C              Z-DIRECTION (M)                                          SIG02700
C     GO TO PROPER SET OF EQUATIONS FOR THIS STABILITY CLASS TO         SIG02800
C       CALCULATE TH FOR THE GIVEN XY, AND CALCULATE SZ FOR THE GIVEN   SIG02900
C       X.  THEN GO TO 80 WHERE SZ IS LIMITED TO 5000 AND SY IS         SIG03000
C       CALCULATED FROM XY AND TH.  RETURN.                             SIG03100
      GO TO (10,20,30,40,50,60,40),KST                                  SIG03200
C         STABILITY A (10)                                              SIG03300
   10 TH = (24.167 - 2.5334*ALOG(XY))/57.2958                           SIG03400
      IF (X-0.15)11,12,12                                               SIG03500
   11 SZ = 158.08 *X ** 1.0542                                          SIG03600
      GO TO 80                                                          SIG03700
   12 IF (X-0.20)13,13,14                                               SIG03800
   13 SZ = 170.22 *X ** 1.0932                                          SIG03900
      GO TO 80                                                          SIG04000
   14 IF (X-0.25)15,15,16                                               S3004100
   15 SZ = 179.52 *X ** 1.1262                                          S3004200
      GO TO 80                                                          S3004300
   16 IF (X-0.30)17,17,18                                               S3004400
   17 SZ = 217.41 *X ** 1.2644                                          S3004500
      GO TO 80                                                          S3004600
   18 IF (X-0.40)19,19,20                                               S3004700
   19 SZ = 258.89 *X ** 1.4094                                          S3004800
      GO TO 80                                                          S3004900
   20 IF (X-0.50)21,21,22                                               S3005000
   21 SZ = 346.75 *X ** 1.7283                                          S3005100
      GO TO 80                                                          S3005200
   22 IF (X-3.11)23,23,24                                               S3005300
   23 SZ = 453.85 *X ** 2.1166                                          S3005400
      GO TO 80                                                          S3005500
   24 SZ = 5000.                                                        S3005600
      GO TO 80                                                          S3005700
C        STABILITY B (30)                                               S3005800
   30 TH = (18.333 - 1.8096*ALOG(X))/57.2958                            S3005900
      IF (X-0.2)31,31,32                                                S3006000
   31 SZ = 90.673 *X ** 0.93198                                         S3006100
      GO TO 80                                                          S3006200
   32 IF (X-0.4)33,33,34                                                S3006300
   33 SZ = 98.483 *X ** 0.98332                                         S3006400
      GO TO 80                                                          S3006500
   34 SZ = 109.30 *X ** 1.0971                                          S3006600
      GO TO 80                                                          S3006700
C        STABILITY C (40)                                               S3006800
   40 TH = (12.5 - 1.0857*ALOG(X))/57.2958                              S3006900
      SZ = 61.141 *X ** 0.91465                                         S3007000
      GO TO 80                                                          S3007100
C        STABILITY D2 OR D (42)                                         S3007200
   42 TH = (8.3333-0.72382*ALOG(X))/57.2958                             S3007300
      IF (X-0.3)41,41,39                                                S3007400
   41 SZ = 34.459 *X ** 0.86974                                         S3007500
      GO TO 80                                                          S3007600
   39 IF (X-1.0)43,43,44                                                S3007700
   43 SZ = 32.093 *X ** 0.81066                                         S3007800
      GO TO 80                                                          S3007900
   44 IF (X-3.0)45,45,46                                                S3008000
   45 SZ = 32.093 *X ** 0.64403                                 SIG08100
      GO TO 90                                                  SIG08200
   46 IF (X-10.)47,47,48                                        SIG08300
   47 SZ = 33.504 *X ** 0.60486                                 SIG08400
      GO TO 90                                                  SIG08500
   48 IF (X-30.)49,49,50                                        SIG08600
   49 SZ = 36.650 *X ** 0.56589                                 SIG08700
      GO TO 90                                                  SIG08800
   50 SZ = 44.053 *X ** 0.51179                                 SIG08900
      GO TO 90                                                  SIG09000
C        STABILITY E (52)                                       SIG09100
   52 TH = (6.25 - 0.54287*ALOG(X))/57.2958                     SIG09200
      IF (X-0.3)53,53,54                                        SIG09300
   53 SZ = 23.331 *X ** 0.81956                                 SIG09400
      GO TO 90                                                  SIG09500
   54 IF (X-1.)55,55,56                                         SIG09600
   55 SZ = 21.628 *X ** 0.75660                                 SIG09700
      GO TO 90                                                  SIG09800
   56 IF (X-2.)57,57,58                                         SIG09900
   57 SZ = 21.628 *X ** 0.63077                                 SIG10000
      GO TO 90                                                  SIG10100
   58 IF (X-4.)59,59,60                                         SIG10200
   59 SZ = 22.534 *X ** 0.57154                                 SIG10300
      GO TO 90                                                  SIG10400
   60 IF (X-10.)61,61,62                                        SIG10500
   61 SZ = 24.703 *X ** 0.50527                                 SIG10600
      GO TO 90                                                  SIG10700
   62 IF (X-20.)63,63,64                                        SIG10800
   63 SZ = 26.970 *X ** 0.46713                                 SIG10900
      GO TO 90                                                  SIG11000
   64 IF (X-40.)65,65,66                                        SIG11100
   65 SZ = 35.420 *X ** 0.37615                                 SIG11200
      GO TO 90                                                  SIG11300
   66 SZ = 47.618 *X ** 0.29592                                 SIG11400
      GO TO 90                                                  SIG11500
C        STABILITY F (68)                                       SIG11600
   68 TH = (4.1667 - 0.36191*ALOG(X))/57.2958                   SIG11700
      IF (X-0.2)69,69,70                                        SIG11800
   69 SZ = 15.209 *X ** 0.81558                                 SIG11900
      GO TO 90                                                  SIG12000
```

```
72 IF (X-0.7)73,73,74                                        S2012100
73 SZ = 14.457 *X ** 0.78407                                 S2012200
   GO TO 80                                                  S2012300
74 IF (X-1.)75,75,76                                         S2012400
75 SZ = 13.953 *X ** 0.68465                                 S2012500
   GO TO 80                                                  S2012600
76 IF (X-2.)77,77,78                                         S2012700
77 SZ = 13.953 *X ** 0.63227                                 S2012800
   GO TO 80                                                  S2012900
78 IF (X-3.)79,79,82                                         S2013000
79 SZ = 14.823 *X ** 0.54503                                 S2013100
   GO TO 80                                                  S2013200
82 IF (X-7.)83,83,84                                         S2013300
83 SZ = 16.187 *X ** 0.46490                                 S2013400
   GO TO 80                                                  S2013500
84 IF (X-15.)85,85,86                                        S2013600
85 SZ = 17.836 *X ** 0.41507                                 S2013700
   GO TO 80                                                  S2013800
86 IF (X-30.)87,87,88                                        S2013900
87 SZ = 22.651 *X ** 0.32681                                 S2014000
   GO TO 80                                                  S2014100
88 IF (X-60.)89,89,90                                        S2014200
89 SZ = 27.074 *X ** 0.27436                                 S2014300
   GO TO 80                                                  S2014400
90 SZ = 34.219 *X ** 0.21716                                 S2014500
80 IF (SZ-5000.)96,96,95                                     S2014600
95 SZ = 5000.                                                S2014700
96 SY = 1000.*X*SIN(TH)/(2.15*COS(TH))                       S2014800
   RETURN                                                    S2014900
   END                                                       S2015000
```

SINGLE SOURCE (CRSTER) MODEL - SUBROUTINE BEHGT2

```
      SUBROUTINE BEHGT2   (HF,HX,HMW,F,DELHF,DISTF,DELHX,HP,TS,VS,D,VF, BEH00100
     1 KST,X,U,DTHDZ,T,P)                                               BEH00200
C      BEHGT2   (BRIGGS EFFECTIVE HEIGHT)   OCTOBER 1972                BEH00300
C       THIS DIFFERS FROM THE AUGUST 1972 VERSION IN STATEMENT 24 + 1 BEH00400
C        THE CONSTANT 2.4 PREVIOUSLY WAS 2.5, AND IN STATEMENT 27:      BEH00500
C        THE CONSTANT 3.14159 PREVIOUSLY WAS 2.4 .                      BEH00600
C      D. B. TURNER, RESEARCH METEOROLOGIST, MODEL DEVELOPMENT BRANCH,  BEH00700
C       DIVISION OF METEOROLOGY, ENVIRONMENTAL PROTECTION AGENCY.       BEH00800
C        ROOM 3049, NCHS BUILDING, RTP, PHONE (919) 549-8411 EXT 4564 BEH00900
C        MAILING ADDRESS: D4, EPA, RESEARCH TRIANGLE PARK, NC 27711     BEH01000
C      * ON ASSIGNMENT FROM NATIONAL OCEANIC AND ATMOSPHERIC            BEH01100
C             ADMINISTRATION, DEPARTMENT OF COMMERCE.                   BEH01200
C       FROM A SINGLE SOURCE IS BASED ON:                               BEH01300
C      THIS VERSION OF BRIGGS EFFECTIVE HEIGHT TO CALCULATE PLUME RISE BEH01400
C        1) BRIGGS,GARY A., 1971: SOME RECENT ANALYSES OF PLUME RISE    BEH01500
C           OBSERVATION, PP 1029 - 1032 IN PROCEEDINGS OF THE SECOND    BEH01600
C           INTERNATIONAL CLEAN AIR CONGRESS, EDITED BY H. M. ENGLUND   BEH01700
C           AND W. T. BEERY. ACADEMIC PRESS, NEW YORK.                  BEH01800
C        2) BRIGGS, GARY A.,1972: DISCUSSION ON CHIMNEY PLUMES IN       BEH01900
C           NEUTRAL AND STABLE SURROUNDINGS. ATMOS. ENVIRON. 6: 507     BEH02000
C           - 510. (JUL 72).                                            BEH02100
C       OUTPUT VARIABLES ARE...                                         BEH02200
C        HF     FINAL EFFECTIVE PLUME HEIGHT (METERS)                   BEH02300
C        HX     EFFECTIVE PLUME HEIGHT FOR DISTANCE X (METERS)          BEH02400
C        HMW    HEAT OUTPUT OF SOURCE (MW)                              BEH02500
C        F      BUOYANCY FLUX (M**4/SEC**3)                             BEH02600
C        DELHF  FINAL PLUME RISE (METERS)                               BEH02700
C        DISTF  DISTANCE OF FINAL PLUME RISE FROM SOURCE (KM)           BEH02800
C        DELHX  PLUME RISE AT DISTANCE X (METERS)                       BEH02900
C       INPUT VARIABLES ARE...                                          BEH03000
C        HP     PHYSICAL STACK HEIGHT (METERS)                          BEH03100
C        TS     STACK GAS TEMPERATURE (DEG K)                           BEH03200
C        VS     STACK GAS EXIT VELOCITY (M/SEC)                         BEH03300
C        D      INSIDE STACK DIAMETER (METERS)                          BEH03400
C        VF     STACK GAS VOLUMETRIC FLOW RATE (M**3/SEC)               BEH03500
C        KST    STABILITY (CLASS), SEE PAGE 209 OF PASQUILL,            BEH03600
C                ATMOSPHERIC DISPERSION.  CLASSES DEFINED BY...         BEH03700
C                  1 IS PASQUILL STABILITY CLASS A                      BEH03800
C                  2 IS PASQUILL STABILITY CLASS B                      BEH03900
C                  3 IS PASQUILL STABILITY CLASS C                      BEH04000
```

```
C                   4 IS PASQUILL STABILITY CLASS D                      HED04100
C                   5 IS PASQUILL STABILITY CLASS E                      HED04200
C                   6 IS PASQUILL STABILITY CLASS F                      HED04300
C        U      WIND SPEED (M/SEC)                                       HED04400
C        X      DOWNWIND DISTANCE (KM)                                   HED04500
C        DTHDZ POTENTIAL TEMPERATURE LAPSE RATE (DEG K/METER)            HED04600
C        T      AMBIENT AIR TEMPERATURE (DEG K)                          HED04700
C        P      AMBIENT AIR PRESSURE (MB)                                HED04800
C      THANKS TO DALE COVENTRY FOR HIS HELPFUL DISCUSSION ON             HED04900
C       PROGRAMMING PLUME RISE, TO ROBERT THOMPSON FOR THE COMMENT       HED05000
C       CARDS, AND TO RUSS LEE WHO REVISED THIS ACCORDING TO REFERENCEHED05100
      IF(T)1,1,2                                                         HED05200
C      T = 0. MEANS NO AMBIENT TEMPERATURE GIVEN.  USE T = 293.          HED05300
    1 T = 293.                                                           HED05400
    2 IF(P)3,3,4                                                         HED05500
C      P = 0. MEANS NO AMBIENT AIR PRESSURE GIVEN.  USE P = 960.         HED05600
    3 P = 960.                                                           HED05700
C      IF HF IS NOT GIVEN, CALCULATE IT FROM STACK DATA.                 HED05800
    4 IF(HF)5,5,6                                                        HED05900
    5 VF = 0.785398*VS*D*D                                               HED06000
C      THE CONSTANT 0.785398 = PI/4                                      HED06100
    6 F = 3.12139*VF*(TS-T)/TS                                           HED06200
C      THE CONSTANT 3.12139 IS THE ACCELERATION DUE TO GRAVITY / PI.     HED06300
      HF = 0.00011217*F*P                                                HED06400
C      THE CONSTANT 0.00011217 = PI TIMES THE SPECIFIC HEAT OF AIR AT    HED06500
C       CONSTANT PRESSURE (0.24 CAL/GM-DEG K) TIMES MOLECULAR WEIGHT     HED06600
C       OF AIR (28.966 GM/GM-MOLE) DIVIDED BY IDEAL GAS CONSTANT         HED06700
C       (0.0831 MB*M**3/GM-MOLE-DEG K) AND ACCELERATION DUE TO GRAVITYHED06800
C       (9.80616 M/SEC*SEC) AND THEN MULTIPLIED BY (4.1855E-06 MW/CAL  HED06900
C       PER SEC) TO CONVERT THE ANSWER TO MEGAWATTS.                     HED07000
C      GO TO APPROPRIATE BRANCH FOR STABILITY CONDITION GIVEN.           HED07100
C      IF UNSTABLE OR NEUTRAL GO TO 7, IF STABLE GO TO 20.               HED07200
      GO TO (7,7,7,7,20,20),KST                                          HED07300
C      DETERMINE APPROPRIATE FORMULA FOR CALCULATING XST, DISTANCE AT    HED07400
C       WHICH TURBULENCE BEGINS TO DOMINATE.  THE FORMULA USED DEPENDSHED07500
C       UPON BUOYANCY FLUX, STATEMENTS 8 AND 9 ARE EQUATION (7).         HED07600
    7 IF(F-55.)8,9,9                                                     HED07700
    8 XST=14.*F**.625                                                    HED07800
      GO TO 10                                                           HED07900
    9 XST=34.*F**.4                                                      HED08000
```

```
10     DISTF=3.5*XST
       DELHF=1.6*F**0.3333333*DISTF**0.6666667/U
       IF(X)29,29,32
C         IF X = 0.0, CALCULATE FINAL RISE ONLY, IF X IS GREATER THAN
C          0.0, CALCULATE RISE FOR DISTANCE = X ALSO.
   32 XM = 1000.0*X
C         XM IS X IN METERS.
C         STATEMENT 34 IS EQUATION (6), REFERENCE 1.
   34 DELHX = 1.6*F**0.3333333*XM**0.6666667/U
       IF(DELHX.GT.DELHF)DELHX=DELHF
       GO TO 30
   20 IF(DTHDZ)21,21,24
C         IF DTHDZ IS NEGATIVE OR ZERO ASSIGN TO IT A VALUE OF 0.02 OR
C          0.035 IF STABILITY IS SLIGHTLY STABLE OR STABLE, RESPECTIVELY.
   21 GO TO (7,7,7,7,22,23),KST
   22 DTHDZ = 0.02
       GO TO 24
   23 DTHDZ = 0.035
   24 S = 9.80616*DTHDZ/T
C         THE CONSTANT 9.80616 IS THE ACCELERATION DUE TO GRAVITY.
C         S IS A STABILITY PARAMETER.
C         CALCULATE PLUME RISE ACCORDING TO EQUATION (4), REFERENCE 1.
       DHA = 2.4*(F/(U*S))**0.3333333
C         CALCULATE PLUME RISE BY EQUATION (5), REFERENCE 1 FOR LIGHT
C          WIND CONDITIONS ACCORDING TO MORTON, TAYLOR, AND TURNER.
       DELHF = 5.0*F**0.25/S**0.375
       IF(DHA-DELHF) 25,25,27
   25 DELHF = DHA
C         DISTANCE TO FINAL PLUME RISE IS GIVEN BY THE FOLLOWING
   27 DISTF = 3.14159*U/S**0.5
C         IF X = 0.0, CALCULATE FINAL RISE ONLY, IF X IS GREATER THAN
C          0.0, CALCULATE RISE FOR DISTANCE = X ALSO.
C         IF X IS ZERO OR LESS, GO TO 29 AND SET PLUME RISE AND DIST. TO
C          MAXIMUM PLUME RISE EQUAL TO ZERO.
       IF(X)29,29,33
   33 XM = 1000.*X
C         XM IS X IN METERS.
C         IF XM IS GREATER THAN THE DISTANCE TO THE POINT OF FINAL PLUME
C          RISE, SET PLUME RISE EQUAL TO FINAL PLUME RISE, OTHERWISE,
C          CALCULATE PLUME RISE FROM EQUATION (6),REFERENCE 1.
```

```
      IF(X-DISTF)24,24,28
   28 DELHX = DELHF
      GO TO 30
   24 DELHX = 0.
      HX = 0.
      GO TO 31
C         CALCULATE EFFECTIVE HEIGHT AT DISTANCE X.
   30 HX = HP + DELHX
C         CALCULATE FINAL EFFECTIVE HEIGHT.
   31 HF = HP + DELHF
      DISTF = DISTF/1000.
      RETURN
      END
```

SINGLE SOURCE [illegible] MODEL - BLOCK DATA

```
      BLOCK DATA                                                         BL000100
      COMMON /COM1/DAY(366),TX1(6),TX2(2),TX3(2),TX4(2),                 BL000200
     *ITAP,NS,IVT,IDCH,IHCH,ITCH,                                        BL000300
     *U248(12,28),V248(12,28),T248(12,28)                                BL000400
      COMMON /COM2/CTN1(28,19),CTN3(28,19),CTN4(28,19),CTN24(28,19),     BL000500
     *CTN4H(28,19),ISC1(28),ISC3(28),ISC4(28),ISC24(28),ISC4H(28),       BL000600
     *SC1(40),SC3(40),SC4(40),SC24(40),SC4H(40),IPR(5),ISC,LINE          BL000700
      INTEGER*2 DAY                                                      BL000800
      DATA DAY/366*1,0,0/,NS/0/                                          BL000900
      DATA ITAP,IVT/0,0/                                                 BL001000
      DATA IDCH,IHCH,ITCH/0,0,0/                                         BL001100
      DATA SC1,SC3,SC4,SC24,SC4H/40*0.,40*0.,40*0.,40*0.,40*0./          BL001200
      DATA ISC/0/                                                        BL001300
      DATA LINE,IPR/50,5*0/                                              BL001400
      END                                                                BL001500
```

APPENDIX B
EXAMPLE SINGLE SOURCE (CRSTER) MODEL RUNS

Listings of the input and output data for two example runs of the Single Source (CRSTER) Model are contained in this section. The first example is a standard model run while the second example is a source-contribution run. These examples begin on the following pages:

Example Listing	Page Number
Standard Model Run	
Input Data	B-3
Output Data	B-5
Source-Contribution Run	
Input Data	B-28
Output Data	B-31

INPUT DATA FOR AN EXAMPLE STANDARD RUN OF THE SINGLE SOURCE (CRSTER) MODEL

```
 EXAMPLE RUN             SS2
THIS IS A SINGLE SOURCE (CRSTER) MODEL EXAMPLE RUN.
THIS RUN ILLUSTRATES THE USE OF THE FOLLOWING OPTIONS:
*          STANDARD MODEL RUN
*          DAILY MET PRINTOUT
*          RUN FOR TWENTY DAYS
*          UNEVEN RECEPTOR TERRAIN
*          NO HOURLY OUTPUT TAPE
*          RURAL MIXING HEIGHTS
*          VARIABLE AVERAGING TIME
*          MONTHLY VARIATIONS OF Q** AND T*.
CINCINNATI SURFACE
DAYTON UPPER AIR

 $INPT
 IOPT=1,ITAPE=0,IDAY=12*0,10*1,5*0,10*1,217*0,IHT=0,
 ISCH=1,IVCH=1,ITCH=1,QSS=12*36.22,12*1395.2,12*1086.1,12*3434.4,12*768.38,
 VSS=12*19.42,12*28.19,12*29.77,12*33.63,12*31.58,
 TSS=12*425.0,12*462.0,12*415.0,12*405.0,12*366.0,
 IPT=0,IMET=1,ISS=93814,ISYR=64,IUS=93815,IUY=64,
 PHSH=0.9,1.5,2.0,3.0,4.2,$END
 492.07
1          540.0      580.0      470.0      510.0      440.0
2          550.0      550.0      575.0      660.0      460.0
3          525.0      615.0      625.0      710.0      460.0
4          490.0      720.0      640.0      720.0      540.0
5          440.0      600.0      650.0      455.0      500.0
6          480.0      550.0      580.0      440.0      480.0
7          470.0      480.0      455.0      470.0      720.0
8          470.0      455.0      455.0      720.0      720.0
9          415.0      455.0      480.0      720.0      720.0
10         455.0      455.0      610.0      720.0      720.0
11         455.0      610.0      720.0      720.0      720.0
12         455.0      660.0      660.0      720.0      720.0
13         520.0      590.0      590.0      720.0      720.0
14         610.0      720.0      720.0      720.0      720.0
15         700.0      560.0      560.0      720.0      720.0
16         700.0      530.0      540.0      720.0      720.0
17         680.0      720.0      550.0      720.0      720.0
18         510.0      650.0      580.0      720.0      720.0
```

19	470.0	470.0	650.0	720.0	780.0
20	455.0	600.0	670.0	610.0	720.0
21	455.0	720.0	720.0	540.0	720.0
22	455.0	780.0	720.0	610.0	520.0
23	455.0	455.0	495.0	460.0	455.0
24	460.0	455.0	455.0	460.0	460.0
25	460.0	460.0	475.0	460.0	560.0
26	470.0	460.0	460.0	460.0	720.0
27	490.0	460.0	455.0	460.0	510.0
28	500.0	465.0	455.0	470.0	455.0
29	520.0	475.0	460.0	480.0	470.0
30	610.0	460.0	460.0	490.0	520.0
31	720.0	460.0	470.0	490.0	550.0
32	675.0	460.0	470.0	480.0	720.0
33	630.0	470.0	470.0	470.0	650.0
34	590.0	460.0	470.0	470.0	620.0
35	560.0	460.0	470.0	480.0	600.0
36	540.0	460.0	470.0	480.0	490.0

STACK 1	63.2	3.85
STACK 2	78.7	3.46
STACK 3	114.3	3.35
STACK 4	243.8	5.01

OUTPUT DATA FOR AN EXAMPLE STANDARD RUN OF THE SINGLE SOURCE (CRSTER) MODEL

```
PLANT NAME: EXAMPLE RUN            POLLUTANT: SO2       EMISSION UNITS: GM/SEC     AIR QUALITY UNITS: GM/M**3
THIS IS A SINGLE SOURCE (CRSTER) MODEL EXAMPLE RUN.
THIS RUN ILLUSTRATES THE USE OF THE FOLLOWING OPTIONS:
*          STANDARD MODEL RUN
*          DAILY MET PRINTOUT
*          RUN FOR TWENTY DAYS
*          USER-SPECIFIED TERRAIN
*          NO HOURLY OUTPUT TABLE
*          RURAL MIXING HEIGHTS
*          VARIABLE AVERAGING TIME
*          MONTHLY VARIATIONS OF Q,H AND T.
CONCENTRATION SURFACE
DEPTH LAYER AT

          MET FILE     REQUESTED
          STN NO. YR   STN NO. YR
SURFACE   [illegible]  [illegible]
UPPER AIR [illegible]  [illegible]
PLANT LOCATION: RURAL
NO TAPE OUTPUT
Q VALUES REQUIRE MONTHLY INPUT
H VALUES REQUIRE MONTHLY INPUT
T VALUES REQUIRE MONTHLY INPUT

DAY--> 0000000000 0000000000 0000000000 0000000000 0000000000
       0000000000 0000000000 0000000000 0000000000 0000000000
       0000000000 0000000000 0000111111 1111000001 1111111110
       0000000000 0000000000 0000000000 0000000000 0000000000
       0000000000 0000000000 0000000000 0000000000 0000000000
       0000000000 0000000000 0000000000 0000000000 0000000000
       0000000000 0000000000 0000000000 0000000000 0000000000
       0000000000 000000

* * * * * * * * * * * * * * * * * * * * * * * NOTE * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
    ALL TABLES (EXCLUDING SOURCE CONTRIBUTION) THAT CONTAIN "ANNUAL" IN THE HEADING ARE BASED ONLY ON THOSE DAYS
    MARKED BY "1" IN THE ABOVE TABLE.
```

[illegible]

[illegible] [illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]
[illegible]
[illegible]
[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

MAX HOURLY

MAX 24-HOUR

[illegible]

MAX HOURLY

MAX 24-HOUR

[illegible]

```
[illegible]

              MAX HOURLY                      MAX 24-HOUR

[illegible]

[illegible]

              MAX HOURLY                      MAX 24-HOUR

[illegible]

[illegible]

              MAX HOURLY                      MAX 24-HOUR

[illegible]

[illegible]

              MAX HOURLY                      MAX 24-HOUR

[illegible]
```

```
[illegible]
[illegible]
[illegible]
[illegible]

                    MAX HOURLY                              MAX 24-HOUR

[illegible]
[illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

                    MAX HOURLY                              MAX 24-HOUR

[illegible]
[illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

                    MAX HOURLY                              MAX 24-HOUR

[illegible]
[illegible]

[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]
[illegible]

                    MAX HOURLY                              MAX 24-HOUR

[illegible]
[illegible]
```

[illegible]

M A X   H O U R L Y   M A X   2 4 - H O U R

[illegible]

[illegible]

M A X   H O U R L Y   M A X   2 4 - H O U R

[illegible]

[illegible]

M A X   H O U R L Y   M A X   2 4 - H O U R

[illegible]

[illegible]

M A X   H O U R L Y   M A X   2 4 - H O U R

[illegible]

PLANT NAME: EXAMPLE [illegible] POLLUTANT: SO2 EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

YEARLY MAXIMUM 24-HOUR CONC: [illegible] DIRECTION: 4 DISTANCE: 3.0 KM DAY=[illegible]

HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR

RANGE DIR	.8 KM	1.5 KM	2.2 KM	3.0 KM	4.2 KM
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

```
PLANT NAME: EXAMPLE RUN          POLLUTANT: SO2      EMISSION UNITS: GM/SEC    AIR QUALITY UNITS: GM/M**3

YEARLY SECOND HIGHEST 24-HOUR CONC:  [illegible]  DIRECTION:  4  DISTANCE:  3.0 KM  DAY=[illegible]

              SECOND HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR
  RANGE       .5 KM                1.5 KM               2.0 KM               3.0 KM               4.2 KM
DIR
   1   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
   2   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
   3   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
   4   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
   5   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
   6   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
   7   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
   8   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
   9   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  10   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  11   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  12   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  13   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  14   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  15   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  16   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  17   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  18   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  19   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  20   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  21   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  22   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  23   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  24   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  25   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  26   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  27   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  28   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  29   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  30   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  31   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  32   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  33   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  34   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  35   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
  36   [illegible]          [illegible]          [illegible]          [illegible]          [illegible]
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PLANT NAME: EXAMPLE RUN          POLLUTANT: SO2        EMISSION UNITS: G/SEC      AIR QUALITY UNITS: [illegible]

YEARLY MAXIMUM 3-HOUR CONC: [illegible]  DIRECTION: [illegible]  DISTANCE: [illegible] KM  [illegible]     TIME PERIOD: 2

            HIGHEST 3-HOUR CONCENTRATION AT EACH RECEPTOR
 RANGE      .5 KM               1.5 KM              2.0 KM              3.0 KM              [illegible] KM
 DIR
  1   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
  2   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
  3   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
  4   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
  5   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
  6   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
  7   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
  8   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
  9   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 10   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 11   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 12   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 13   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 14   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 15   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 16   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 17   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 18   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 19   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 20   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 21   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 22   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 23   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 24   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 25   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 26   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 27   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 28   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 29   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 30   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 31   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 32   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 33   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 34   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 35   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
 36   [illegible]         [illegible]         [illegible]         [illegible]         [illegible]
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PLANT NAME: EXAMPLE RUN          POLLUTANT: SO2     EMISSION UNITS: GM/SEC    AIR QUALITY UNITS: GM/M**3

YEARLY SECOND MAXIMUM 3-HOUR CONC:  [illegible]  DIRECTION:  4  DISTANCE:  1.5 KM  DAY=[illegible]   TIME PERIOD: 2

                    SECOND HIGHEST  3-HOUR CONCENTRATION AT EACH RECEPTOR
 RANGE     .5 KM                  1.5 KM                  2.2 KM                  3.0 KM                  4.2 KM
DIR
  1    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  2    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  3    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  4    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  5    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  6    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  7    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  8    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  9    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 10    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 11    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 12    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 13    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 14    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 15    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 16    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 17    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 18    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 19    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 20    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 21    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 22    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 23    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 24    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 25    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 26    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 27    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 28    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 29    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 30    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 31    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 32    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 33    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 34    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 35    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
 36    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
```

PLANT NAME: EXAMPLE RUN POLLUTANT: SO2 EMISSION UNITS: GM/SEC AIR QUALITY UNITS: GM/M**3

YEARLY MAXIMUM 3-HOUR CONC: [illegible] DIRECTION: [illegible] DISTANCE: 1.5 KM DAY: [illegible] TIME PERIOD: 5

HIGHEST 3-HOUR CONCENTRATION AT EACH RECEPTOR

RANGE DIR	.5 KM	1.5 KM	2.0 KM	3.0 KM	6.2 KM
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

PLANT NAME: EXAMPLE RUN   POLLUTANT: SO2   EMISSION UNITS: G/SEC   AIR QUALITY UNITS: UG/M**3

YEARLY SECOND HIGHEST   3-HOUR CONC: [illegible]   DIRECTION: 10   DISTANCE: 3.0 KM   DAY=130   TIME PERIOD: 4

SECOND HIGHEST   3-HOUR CONCENTRATION AT EACH RECEPTOR

RANGE DIR	.5 KM	1.5 KM	2.2 KM	3.0 KM	4.2 KM
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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PLANT NAME: EXAMPLE RUN          POLLUTANT: SO2      EMISSION UNITS: G/SEC    AIR QUALITY UNITS: UG/M**3

YEARLY MAXIMUM 1-HOUR CONC:  2.2594+03  DIRECTION:  5  DISTANCE:  1.5 KM  DAY=142    HOUR=13

              HIGHEST  1-HOUR CONCENTRATION AT EACH RECEPTOR
  RANGE       .8 KM                 1.5 KM                2.8 KM                3.8 KM                6.2 KM
DIR
  1    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
  2    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
  3    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
  4    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
  5    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
  6    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
  7    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
  8    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
  9    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 10    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 11    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 12    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 13    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 14    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 15    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 16    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 17    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 18    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 19    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 20    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 21    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 22    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 23    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 24    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 25    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 26    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 27    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 28    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 29    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 30    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 31    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 32    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 33    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 34    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 35    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
 36    [illegible]           [illegible]           [illegible]           [illegible]           [illegible]
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PLANT NAME: EXAMPLE RUN            POLLUTANT: SO2      EMISSION UNITS: GM/SEC     AIR QUALITY UNITS: GM/M**3

YEARLY SECOND HIGHEST 1-HOUR CONC: [illegible]  DIRECTION:  4  DISTANCE: 1.5 KM  DAY/HR: [illegible]

                SECOND HIGHEST  1-HOUR CONCENTRATION AT EACH RECEPTOR
 RANGE      .5 KM                   1.5 KM                  2.8 KM                  3.8 KM                  5.2 KM
DIR
   1    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
   2    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
   3    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
   4    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
   5    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
   6    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
   7    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
   8    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
   9    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  10    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  11    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  12    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  13    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  14    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  15    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  16    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  17    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  18    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  19    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  20    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  21    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  22    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  23    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  24    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  25    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  26    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  27    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  28    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  29    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  30    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  31    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  32    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  33    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  34    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  35    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
  36    [illegible]             [illegible]             [illegible]             [illegible]             [illegible]
```

PLANT NAME: EXAMPLE RUN   POLLUTANT: SO2   EMISSION UNITS: GM/SEC   AIR QUALITY UNITS: GM/M**3

MAXIMUM DAILY CONCENTRATIONS

DAY	24-HOUR CONCENTRATION	DIRECTION	DISTANCE
129	2.4770E-04	4	3.00
140	2.3860E-04	7	6.20
145	2.0290E-04	4	1.50
141	1.9810E-04	20	2.00
126	1.8967E-04	4	3.00
127	1.8580E-04	3	3.00
138	1.8459E-04	7	6.20
128	1.7147E-04	4	3.00
147	1.6083E-04	15	1.50
131	1.6547E-04	10	3.00
139	1.5310E-04	7	6.20
146	1.4285E-04	26	2.20
135	1.3245E-04	2	3.00
144	1.2320E-04	4	3.00
148	1.2135E-04	15	3.00
143	9.6230E-05	6	2.00
137	9.1380E-05	3	3.00
132	8.6750E-05	30	6.20
133	8.5910E-05	7	6.20
134	5.6760E-05	21	6.20

```
PLANT NAME: EXAMPLE RUN              POLLUTANT: SO2      EMISSION UNITS: GM/SEC     AIR QUALITY UNITS: GM/M**3

                                                      MAXIMUM 8-HOURLY CONCENTRATIONS

                                     DAY       8-HOUR CONCENTRATION    DIRECTION    DISTANCE      TIME PERIOD

                                     141            5.6105-04              10          2.00            2
                                     140            5.3973-04               7          6.20            2
                                     128            5.1999-04               4          3.00            2
                                     142            4.9436-04              15          1.50            2
                                     128            4.8776-04               4          2.00            2
                                     128            4.8665-04               4          1.20            2
                                     145            4.8158-04               4          1.50            2
                                     128            4.6755-04               3          2.00            2
                                     145            4.5665-04               5          1.50            2
                                     142            4.5362-04              15           .90            2
                                     141            4.3698-04              20          3.00            2
                                     129            4.2938-04               4          3.00            3
                                     146            4.2854-04              26          2.00            2
                                     145            4.2190-04               5          2.00            2
                                     142            3.9832-04              15          2.00            2
                                     146            3.9753-04              26          3.00            2
                                     141            3.9329-04              21          2.20            2
                                     128            3.9064-04               2          3.00            2
                                     142            3.8264-04              14          1.50            2
                                     138            3.8145-04               2          2.00            2
                                     128            3.8076-04               3          1.50            2
                                     128            3.7737-04               3          3.00            2
                                     127            3.7622-04               3          3.00            2
                                     141            3.5469-04              20          3.20            2
                                     131            3.5253-04              18          3.00            2
                                     146            3.5206-04              25          2.00            2
                                     146            3.5187-04              25          3.00            2
                                     142            3.4784-04              14           .90            2
                                     125            3.4479-04              16          1.50            2
                                     127            3.3680-04               4          1.50            2
                                     127            3.3370-04               4          3.20            2
                                     125            3.3359-04              15          2.00            2
                                     128            3.3284-04               4          3.20            2
                                     138            3.3253-04              18          3.00            2
                                     141            3.2799-04              21          1.50            2
                                     129            3.2707-04               3          3.00            2
                                     142            3.2373-04               5          1.97            2
                                     126            3.2243-04               8          3.40            2
                                     142            3.2198-04              16          1.50            2
                                     145            3.2192-04               4          3.00            2
                                     131            3.1881-04               9          3.00            2
                                     128            3.1748-04               7          6.20            2
                                     125            3.1732-04              16          2.00            2
                                     140            3.1718-04              17          3.00            2
                                     141            3.1577-04              22          2.00            2
                                     125            3.1545-04              18           .90            2
                                     127            3.1439-04               3          2.00            2
                                     125            3.1383-04              16          1.50            2
                                     146            3.1128-04               5          2.20            2
                                     140            3.1084-04               7          3.00            2
```

PLANT NAME: EXAMPLE RUN   POLLUTANT: SO2   EMISSION UNITS: GM/SEC   AIR QUALITY UNITS: GM/M**3

MAXIMUM 3-HOURLY CONCENTRATIONS

DAY	3-HOUR CONCENTRATION	DIRECTION	DISTANCE	TIME PERIOD
145	1.0231E-03	4	1.50	5
125	8.7991E-04	35	1.50	5
142	8.6327E-04	5	1.50	5
129	8.5271E-04	4	3.60	8
141	8.4659E-04	23	2.00	5
128	8.4057E-04	3	2.00	5
125	8.2753E-04	35	2.00	5
125	8.0872E-04	32	.90	4
129	7.9109E-04	3	3.60	4
125	7.7056E-04	34	2.00	5
143	7.6241E-04	6	2.00	4
142	7.5871E-04	15	1.50	5
142	7.4458E-04	15	.40	4
125	7.2993E-04	34	1.50	5
128	7.1938E-04	3	1.50	5
131	7.0891E-04	10	5.15	8
142	7.0022E-04	5	2.00	5
130	6.9140E-04	13	3.60	4
125	6.8883E-04	3	2.00	4
142	6.8648E-04	4	1.50	5
142	6.7459E-04	14	.90	4
125	6.6259E-04	35	.90	5
146	6.5145E-04	25	3.60	4
145	6.4980E-04	5	1.50	5
130	6.4675E-04	13	2.00	4
145	6.4453E-04	4	3.60	5
130	6.4130E-04	7	6.20	5
130	6.3550E-04	4	3.60	1
131	6.3444E-04	10	6.20	6
142	6.1945E-04	15	2.00	5
146	6.1772E-04	22	.90	5
146	6.0972E-04	26	2.00	5
129	6.0893E-04	3	3.60	5
143	6.0730E-04	24	.40	5
143	6.0730E-04	25	.90	5
125	6.0325E-04	11	.90	4
127	6.0285E-04	4	1.50	5
128	6.0155E-04	4	1.50	5
141	6.0063E-04	23	2.00	4
134	5.9486E-04	7	6.20	6
125	5.9800E-04	35	3.60	5
142	5.9382E-04	16	1.50	5
125	5.9236E-04	34	3.60	1
144	5.9171E-04	4	3.60	4
143	5.9141E-04	6	1.50	4
128	5.8657E-04	2	2.00	4
146	5.7813E-04	23	3.60	4
145	5.7567E-04	7	3.60	4
140	5.7562E-04	7	6.20	3
142	5.7561E-04	14	1.50	4

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PLANT NAME: EXAMPLE RUN          POLLUTANT: SO2       EMISSION UNITS: GM/SEC    AIR QUALITY UNITS: GM/M**3

                                          MAXIMUM HOURLY CONCENTRATIONS

                        DAY    1-HOUR CONCENTRATION    DIRECTION    DISTANCE    HOUR

                        142        2.5899E-03              5          1.50       13
                        125        2.4862E-03             32           .70       12
                        142        2.2521E-03             15          1.50       14
                        142        2.2137E-03             15           .70       12
                        142        2.1887E-03              5          2.00       13
                        142        2.0595E-03              4          1.50       13
                        142        2.0230E-03             14           .70       12
                        142        1.8551E-03             15          3.00       14
                        146        1.8532E-03             22           .70       13
                        143        1.8219E-03             24           .70       14
                        143        1.8219E-03             25           .70       14
                        125        1.8097E-03             31           .70       12
                        145        1.7929E-03              4          1.50       15
                        142        1.7815E-03             16          1.50       14
                        125        1.7658E-03             35           .70       14
                        127        1.7511E-03              4          1.50       13
                        142        1.7292E-03             14          1.50       12
                        142        1.7187E-03             15          1.50       12
                        140        1.6521E-03             14          2.00       13
                        125        1.6423E-03             33           .70       12
                        142        1.6386E-03              4          2.00       13
                        145        1.6090E-03              5          1.50       14
                        125        1.6071E-03             35          1.50       14
                        146        1.5274E-03             14          1.50       13
                        141        1.5114E-03             11          2.00       14
                        146        1.5102E-03             23           .70       13
                        142        1.4995E-03              6          1.50       13
                        146        1.4932E-03             22          1.50       11
                        142        1.4472E-03             16          2.00       14
                        125        1.4430E-03             32          1.50       12
                        128        1.3998E-03              3          2.00       14
                        142        1.3952E-03             15           .70       14
                        145        1.3933E-03             11          2.00       17
                        141        1.3925E-03             20          2.00       13
                        141        1.3779E-03             22          2.00       14
                        128        1.3567E-03              3          1.50       14
                        141        1.3570E-03             22          3.00        9
                        142        1.3352E-03             14          1.50        9
                        142        1.3313E-03             14          2.00       12
                        142        1.3313E-03             15          2.00       12
                        140        1.3128E-03              9          3.00       15
                        125        1.3098E-03             36           .70       14
                        138        1.3070E-03              8          3.00        7
                        143        1.2885E-03             25          1.50       14
                        143        1.2795E-03             24          1.50       14
                        145        1.2743E-03              4          3.00       15
                        128        1.2713E-03              4          3.00       22
                        125        1.2570E-03              3          2.00       10
                        145        1.2384E-03             11          3.00       17
                        144        1.2305E-03              3          3.00        9
```

INPUT DATA FOR AN EXAMPLE SOURCE-CONTRIBUTION RUN OF THE SINGLE SOURCE (CRSTER) MODEL

```
 EXAMPLE RUN              SO2
THIS IS A SINGLE SOURCE (CRSTER) MODEL EXAMPLE RUN.
THIS RUN ILLUSTRATES THE USE OF THE FOLLOWING OPTIONS:
*        SOURCE CONTRIBUTION
*        RUN FOR A SINGLE DAY
*        UNEVEN RECEPTOR TERRAIN
*        NO HOURLY OUTPUT TAPE
*        RURAL MIXING HEIGHTS
*        VARIABLE AVERAGING TIME
CINCINNATI SURFACE
DAYTON UPPER AIR

 &NAME
 ISC=1,
 SC1=.9,1.,.9,2.,.9,3.,.9,4.,
 SC3=1.5,1.,1.5,2.,1.5,3.,1.5,4.,
 SCW=2.,1.,2.,2.,2.,3.,2.,4.,
 SC24=3.8,1.,3.8,2.,3.8,3.,3.8,4.,
 SCA=6.2,1.,6.2,2.,6.2,3.,6.2,4.,
 IUR=1,ITAP=0,DAY=0,1,364*0,IVT=0,
 IPTZ=1,IMET=0,ISS=93814,ISY=64,IUS=93815,IUY=64,
 RHG=0.9,1.5,2.0,3.0,6.2,&END
 497.00
 1         540.0      500.0      470.0      510.0      460.0
 2         550.0      550.0      575.0      660.0      460.0
 3         525.0      615.0      625.0      710.0      460.0
 4         490.0      720.0      640.0      720.0      540.0
 5         490.0      680.0      650.0      455.0      500.0
 6         480.0      550.0      580.0      490.0      490.0
 7         470.0      480.0      455.0      470.0      720.0
 8         470.0      455.0      455.0      720.0      720.0
 9         455.0      455.0      490.0      720.0      720.0
10         455.0      455.0      610.0      720.0      720.0
11         455.0      610.0      720.0      720.0      720.0
12         455.0      660.0      560.0      720.0      720.0
13         520.0      590.0      590.0      720.0      720.0
14         610.0      720.0      720.0      720.0      720.0
15         700.0      560.0      560.0      720.0      720.0
16         700.0      530.0      540.0      720.0      720.0
17         600.0      720.0      557.0      720.0      720.0
```

```
18          510.0     650.0     580.0     720.0     720.0
19          470.0     470.0     650.0     720.0     700.0
20          455.0     600.0     670.0     610.0     720.0
21          425.0     720.0     720.0     590.0     720.0
22          455.0     700.0     720.0     610.0     520.0
23          455.0     455.0     495.0     460.0     455.0
24          460.0     455.0     455.0     460.0     460.0
25          460.0     460.0     470.0     480.0     560.0
26          475.0     460.0     460.0     460.0     720.0
27          480.0     460.0     455.0     460.0     510.0
28          500.0     465.0     455.0     470.0     455.0
29          530.0     475.0     460.0     480.0     470.0
30          610.0     460.0     465.0     490.0     520.0
31          720.0     460.0     470.0     495.0     550.0
32          675.0     460.0     470.0     480.0     720.0
33          630.0     470.0     470.0     470.0     650.0
34          570.0     460.0     470.0     470.0     620.0
35          560.0     460.0     470.0     480.0     600.0
36          545.0     460.0     470.0     480.0     480.0

  STACK 1
36.22                 83.2      3.05      19.42     428.0
  STACK 2
1395.2                70.7      3.96      28.19     462.0
  STACK 3
1086.1                114.3     2.35      28.77     415.0
  STACK 4
3434.8                243.8     5.91      33.83     485.0
```

OUTPUT DATA FROM AN EXAMPLE SOURCE-CONTRIBUTION RUN OF THE SINGLE SOURCE (CRSTER) MODEL

```
PLANT NAME:  EXAMPLE RUN                 POLLUTANT: SO2      EMISSION UNITS: GM/SEC    AIR QUALITY UNITS: UGM/M**3
THIS IS A SINGLE SOURCE (CRSTER) MODEL EXAMPLE RUN.
THIS RUN ILLUSTRATES THE USE OF THE FOLLOWING OPTIONS:
*          SOURCE CONTRIBUTION
*          RUN FOR A SINGLE DAY
*          UNEVEN RECEPTOR TERRAIN
*          NO HOURLY OUTPUT TAPE
*          RURAL MIXING HEIGHTS
*          VARIABLE AVERAGING TIME
CINCINNATI SURFACE
DAYTON UPPER AIR

              MET FILE     REQUESTED
             STN NO. YR   STN NO. YR
 SURFACE     93814  64    93814  64
 UPPER AIR   93815  64    93815  64
PLANT LOCATION: RURAL
NO TAPE OUTPUT
MET DATA WILL NOT BE PRINTED

DAY--> 0 1 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
       0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
       0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
       0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
       0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
       0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
       0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
       0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0

* * * * * * * * * * * * * * * * * * * * * * * * * N O T E * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
          ALL TABLES, INCLUDING SOURCE CONTRIBUTION, THAT CONTAIN "ANNUAL" IN THE HEADING ARE BASED ONLY ON THOSE DAYS
          MARKED BY "1" IN THE ABOVE TABLE
```

RING DISTANCES(KM): .80 1.30 2.00 3.00 4.20

PLANT ELEVATION (FEET ABOVE SEA LEVEL)— [illegible]

PLANT ELEVATION (METERS ABOVE SEA LEVEL)— [illegible]

DIRECTION	RECEPTOR ELEVATIONS (FEET ABOVE SEA LEVEL) RING#1	RING#2	RING#3	RING#4	RING#5	RECEPTOR ELEVATIONS (METERS ABOVE SEA LEVEL) RING#1	RING#2	RING#3	RING#4	RING#5
1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

STACK # 1— STACK 1
STACK # 2— STACK 2
STACK # 3— STACK 3
STACK # 4— STACK 4

RECEPTOR ELEVATION LESS THAN PLANT ELEVATION - - - RECEPTOR ELEVATION SET TO PLANT ELEVATION - [illegible] TIMES

STACK	MONTH	EMISSION RATE (GM/SEC)	HEIGHT (METERS)	DIAMETER (METERS)	EXIT VELOCITY (M/SEC)	TEMP (DEG.K)	VOLUMETRIC FLOW (M**3/SEC)
1	ALL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	ALL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	ALL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	ALL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

```
PLANT NAME: EXAMPLE RUN          POLLUTANT: SO2       EMISSION UNITS: G/SEC    AIR QUALITY UNITS: UG/M**3

                                         SOURCE CONTRIBUTION TABLE         NO. OF SOURCES: 4

JNT DAY PER WDR  SOURCE 1  SOURCE 2  SOURCE 3  SOURCE 4  SOURCE 5  SOURCE 6  SOURCE 7  SOURCE 8  SOURCE 9  SOURCE 10     TOTAL
[illegible]
```

PLANT NAME: EXAMPLE RUN   POLLUTANT: SO2   EMISSION UNITS: G/SEC   AIR QUALITY UNITS: GRAMS/M**3

SOURCE CONTRIBUTION TABLE   NO. OF SOURCES: 4

[illegible]	DAY	[illegible]	HOUR	SOURCE 1	SOURCE 2	SOURCE 3	SOURCE 4	SOURCE 5	SOURCE 6	SOURCE 7	SOURCE 8	SOURCE 9	SOURCE 10	TOTAL
3	2	3	2/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	2	3	2/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	10	1/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	10	1/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	10	1/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	10	1/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	11	1/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	11	1/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	11	1/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	11	1/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	12	1/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	12	1/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	12	1/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	12	1/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	2	4	2/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	2	4	2/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	2	4	2/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	2	4	2/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	13	1/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	13	1/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	13	1/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	13	1/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	14	1/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	14	1/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	14	1/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	14	1/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	15	1/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	15	1/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	15	1/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	15	1/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	2	5	2/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	2	5	2/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	2	5	2/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	2	5	2/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	16	1/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	16	1/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	16	1/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	16	1/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	2	2	3/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	2	2	3/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	2	2	3/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	2	2	3/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	17	1/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	17	1/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	17	1/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	17	1/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	18	1/ 1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	18	1/ 2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	18	1/ 3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	18	1/ 4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

```
                                        SOURCE CONTRIBUTION TABLE          NO. OF SOURCES:  4

              SOURCE 1  SOURCE 2  SOURCE 3  SOURCE 4  SOURCE 5  SOURCE 6  SOURCE 7  SOURCE 8  SOURCE 9  SOURCE 10     TOTAL
```

APPENDIX C

CODING FORMS FOR CARD INPUT TO THE PREPROCESSOR AND SINGLE SOURCE (CRSTER) MODEL PROGRAMS

The coding form in Figure C-1 can be used to prepare the initialization card and mixing height cards for input to the Preprocessor programs.

The coding form in Figure C-2 can be used to prepare the heading, comment and namelist input cards for the Single Source (CRSTER) Model.

Figure C-3 is a coding form for preparing the plant and receptor terrain elevation for input to the Single Source (CRSTER) Model.

Figure C-4 is a coding form for preparing the stack input data required for input to the Single Source (CRSTER) Model.

PREP INITIALIZATION CARDS

Surface Station Number	[illegible]	[illegible]	[illegible]	[illegible]	Surface Station Latitude (deg)	Surface Station Longitude (deg)	[illegible]	[illegible]	Random Number Seed
					.	.			

MIXING HEIGHT DATA CARDS

Upper Air Station Number	[illegible]	[illegible]	[illegible]	[illegible]	Morning Mixing Height (m)	Afternoon Mixing Height (m)
		1 0	0 1			
		1	1			
		1	2			
		1	3			
		1	4			
		1	5			
		1	6			
		1	7			
		1	8			
		1	9			
		1	1 0			
		1	1 1			
		1	1 2			
		1	1 3			
		1	1 4			
		1	1 5			
		1	1 6			
		1	1 7			
		1	1 8			
		1	1 9			
		1	2 0			
		1	2 1			
		1	2 2			
		1	2 3			
		1	2 4			

FIGURE C-1

PREPROCESSOR INPUT DATA CODING FORMS

MIXING HEIGHT DATA CARDS (Continued)

Upper Air Station Number	[illegible]	[illegible]	[illegible]	Morning Mixing Height (m)		Afternoon Mixing Height(m)	

FIGURE C-1 (CONTINUED)

PREPROCESSOR INPUT DATA CODING FORMS

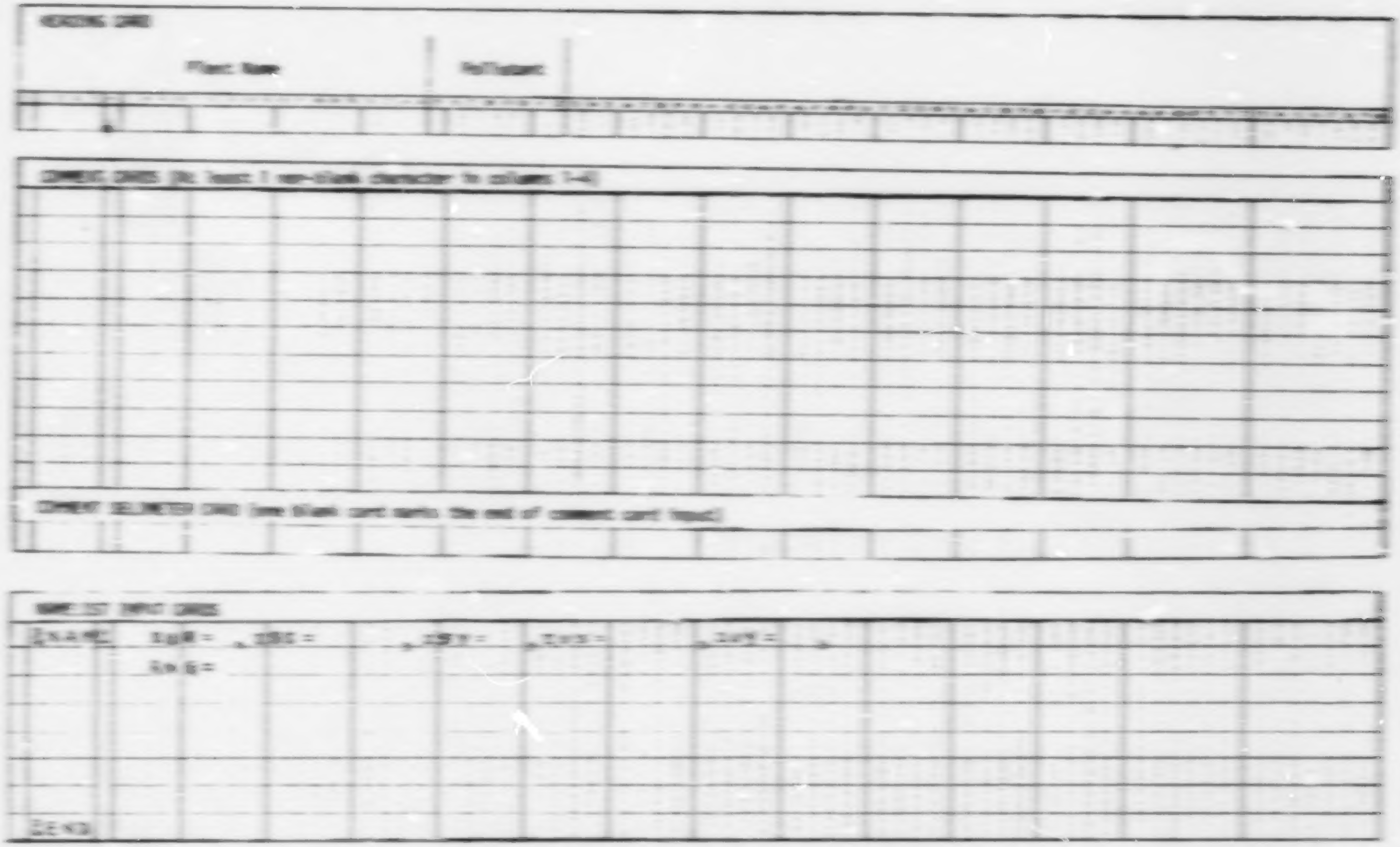

HEADING CARD
Plant Name
Pollutant
COMMENT CARDS (At least 1 non-blank character in columns 1-4)
COMMENT DELIMITER CARD (one blank card marks the end of comment card input)
NAMELIST INPUT CARDS
$NAME
&END

FIGURE C-2

SINGLE SOURCE (CRSTER) MODEL INPUT DATA CODING FORM

PLANT ELEVATION CARD (ft MSL)

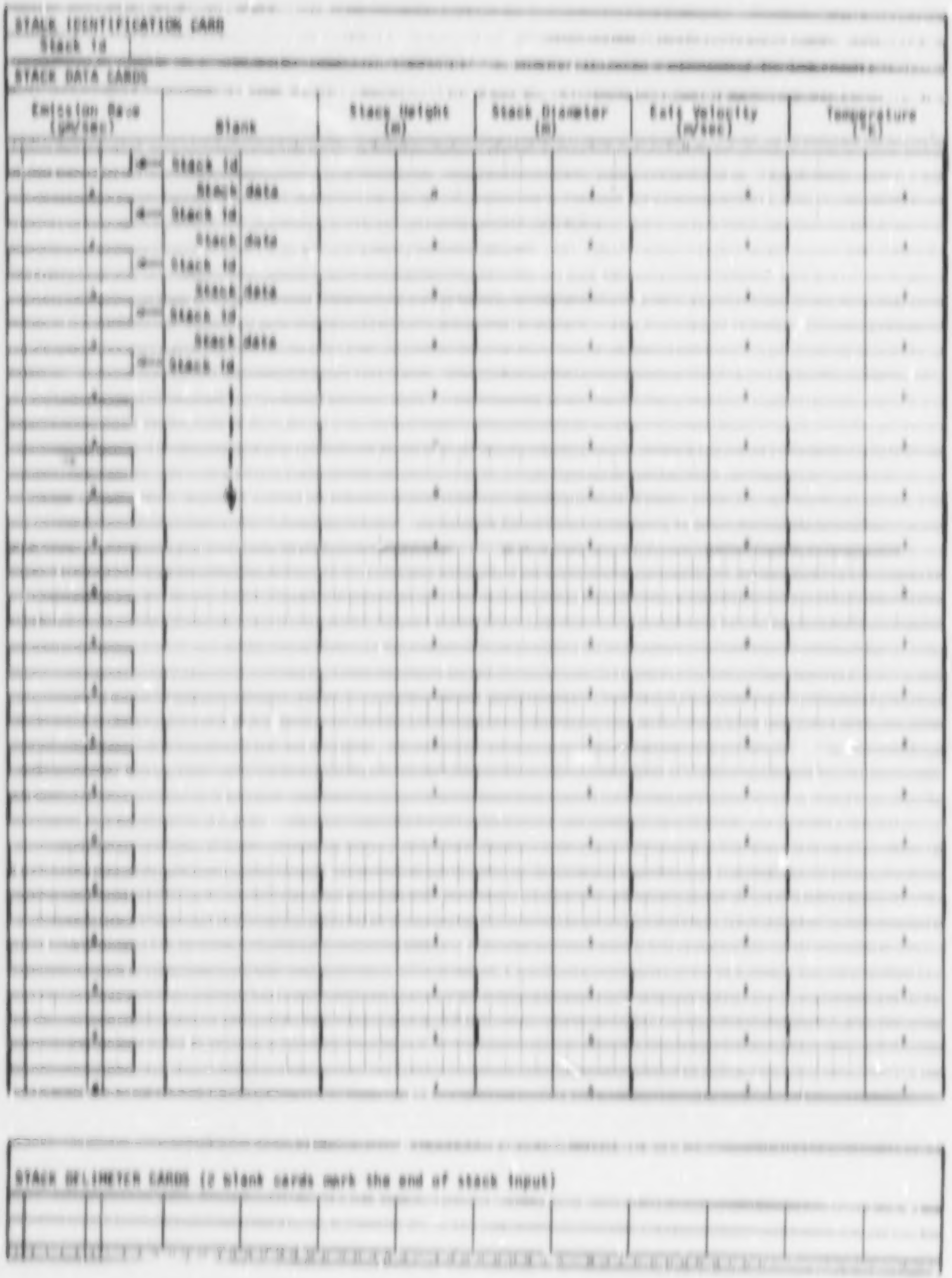
RECEPTOR ELEVATION CARDS

[illegible]	Elevation (ft MSL)				
	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					

RECEPTOR ELEVATION DELIMETER CARD (one blank card marks the end of receptor elevation input)

FIGURE C-3

SINGLE SOURCE (CRSTER) MODEL TERRAIN ELEVATION CODING FORM



STACK IDENTIFICATION CARD

Stack id

STACK DATA CARDS

Emission Rate (gm/sec)	Blank	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/sec)	Temperature (°K)
←	Stack id				
	Stack data				
←	Stack id				
	Stack data				
←	Stack id				
	Stack data				
←	Stack id				
	Stack data				
←	Stack id				

STACK DELIMETER CARDS (2 blank cards mark the end of stack input)

FIGURE C-6

SINGLE SOURCE (CRSTER) MODEL STACK DATA CODING FORM

APPENDIX D

APPLICATIONS OF THE SINGLE SOURCE (CRSTER) MODEL TO POWER PLANTS: A SUMMARY

by

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APPLICATIONS OF THE SINGLE SOURCE (CRSTER) MODEL TO POWER PLANTS: A SUMMARY

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Summary

For the last three years the Environmental Protection Agency has conducted a series of atmospheric dispersion model studies of power plants. These studies have considered the impact of approximately 200 utility power plants whose generating capacity is 25 megawatts or greater. Included in these studies are (1) dispersion model estimates of SO_2 concentrations downwind from each power plant, (2) validation of the Single Source Model with data for several typical power plants and (3) a sensitivity analysis of this model. The results of these studies have been used effectively in a number of energy/environmental policy considerations. This paper summarizes the findings of the various studies.

Introduction

Shortages in the availability of low-sulfur fossil fuels have been given national prominence. These shortages are particularly significant to utility power plants for two reasons: (1) power plants typically use large quantities of fossil fuels and (2) many of the State Implementation Plans (SIPs) require severe reductions in sulfur dioxide emissions from power plants which burn fossil fuels. The shortage of low-sulfur fuel necessitates the elimination of unduly stringent SIP control regulations, where this can be done without endangering air quality standards. The fuel shortage has also led to legislation which empowers the Federal Energy Administration to require that specific power plants switch from oil or gas to coal. This switch to coal, however, cannot be allowed to result in a threat to air quality standards. Furthermore, to meet the Clean Air Act requirement for attainment and maintenance of acceptable air quality, it may be necessary to revise the SIPs for selected source categories, including power plants. The power plant studies summarized in this paper support actions like those noted above.

Estimates of the air quality impact caused by power plants are major components of these studies. A dispersion model is a commonly used technique for relating pollutant emissions to ambient air quality. It is a mathematical description of pollutant transport, dispersion and transformation processes that occur in the atmosphere. The Single Source (CRSTER) Model is the primary dispersion model applied in all the power plant studies discussed in this summary paper.

Due to severe time constraints and the fact that models like the Single Source Model are widely applied and considered state-of-the-art, the accuracy of this model was not analyzed in the initial phase of the power plant studies. However, some analyses of the Single Source Model have been recently completed and others are continuing. These include validation studies, sensitivity analysis and model improvement.

Following sections of this paper discuss (1) the Single Source Model, (2) power plant studies in which it is applied, (3) evaluation of the model through validation and a sensitivity analysis, and (4) applications to energy/environmental policy considerations.

Single Source (CRSTER) Model

The Single Source (CRSTER) Model is a Gaussian plume model. It is based on the dispersion coefficients and equations described by Turner[1] and on the plume rise equations described by Briggs[2]. The model is essentially the same as that discussed by Hrenko et al[3]. It is designed to estimate concentrations for averaging times of 1 hour, 24 hours, and 1 year due to sources at a single location. The concentrations are estimated for a circular array of receptor sites which are located so as to approximate the downwind distances at which the highest concentrations are likely to occur.

The model estimates concentrations for each hour of a year, based on wind direction (in increments of 10 degrees), wind speed, Pasquill stability class, and mixing height. Meteorological surface data for 1964 are frequently used in the power plant studies, although, with the proper data, any year could be used. The reasons for the routine use of 1964 meteorological data are (1) data from earlier years do not have an adequate resolution of wind direction, and (2) data from subsequent years are not readily available on an hourly basis. Mixing height data are from the upper air observations made at selected National Weather Service stations. Hourly mixing heights are estimated within the model by use of an objective interpolation scheme. Decay of the pollutant between source and receptor is ignored.

To simulate the effect of elevated terrain in the vicinity of plant sites, a terrain adjustment procedure is used. This procedure decreases the effective plume height by an amount equal to the difference in elevation between the plant site and the specific receptor site. The model then uses the adjusted plume height in estimating concentrations at that receptor. In those cases where terrain features are found to be greater than the effective plume height of the plant, the Single Source Model is not applied.

Power Plant Studies

Purpose and Limitations

The power plant studies have considered the impact of approximately 700 utility power plants whose generating capacity is 25 megawatts or greater. The studies may be divided into three parts. These are analyses for (1) the feasibility of compliance extensions in 51 selected Air Quality Control Regions (AQCRs), (2) the feasibility of oil-to-coal conversions at selected power plants and (3) the general impact of power plants on ambient SO_2 concentrations in 128 AQCRs. In all cases the studies are primarily concerned with estimates of the maximum 24-hour concentrations of SO_2. This averaging time and this pollutant are the critical ones for which power plants must meet Primary National Ambient Air Quality Standards (NAAQS). The second study is the only one which considers particulate concentrations. Also, in those cases where it is estimated that neighboring power plants could contribute concentrations which add to those caused by the plant under consideration, an interaction analysis is performed.

All source data used in the power plant studies are taken from the Federal Power Commission (FPC Form 67) for the year of 1970 or 1971. In those cases where emissions are projected to 1975, appropriate data are taken from "Steam Electric Plant Factors"[4].

Emissions data are based on average monthly operations for each month of the year. Such monthly data are the finest time resolution available from the FPC. Since a power plant could quite possibly operate at 100 percent of rated capacity for 24 hours, which would not be apparent from the monthly data, it is possible that days of peak operation were coincident with days of poor dispersion conditions. The estimated maximum concentrations could be significantly low. Thus, two sets of emission conditions are routinely considered. One is the nominal load case in which average hourly emission rates are used; they are assumed to be constant except for variations by month. The other is the maximum load case where emissions and plume rise are based on the plant continuously operating at 85 percent of rated capacity. Both sets of emissions data are considered and the one which results in the highest estimated concentrations is used.

It should be noted that any use of these studies must recognize the inherent limitations resulting from the data and procedures used in the modeling effort. Before final judgment on the control of specific plants is made, other factors, not addressed in these studies, should be considered. These include the impact of other sources in the area, projected growth in the area, measured air quality data, known or suspected downdraft or fumigation problems, unique nearby terrain features, nearby land use patterns and population distributions, more specific operational data for the plant, impact of new units, specific meteorological studies for the area, and additional studies or findings by other investigators.

Compliance Extension Studies

In 1972 a study by EPA on the aggregate demand created by the SIPs for low-sulfur coal was conducted. This study indicated a nationwide potential deficit of about 100 million tons/year of such coal by 1975. The deficit was considered most acute in 17 states with high coal consumption rates. One means to alleviate the deficit would be to selectively reduce the requirements for low-sulfur coal in those cases where a higher sulfur coal could be used without endangering the NAAQS.

An initial modeling study of SO_2 emissions in several AQCRs had been conducted. This study showed that some of the large power plants could be temporarily allowed to burn coal at 1970 sulfur levels without threatening the 24-hour NAAQS. Based on the results of this study, it was decided to consider selected power plants in 17 states which are heavily dependent on coal. This involved a total of approximately 200 power plants in 51 AQCRs.

The study[5,6] finds that at approximately 50 percent of the plants considered, some relaxation of emission limitations is possible. Relaxation could result in increasing the average allowable percent sulfur content of fuel from approximately 1 percent sulfur content to 2 percent sulfur content at the plants considered. Thus, the projected deficit in low-sulfur coal could be eliminated.

Fuel Conversion Studies

The compliance extension studies discussed in the preceding section had been conducted prior to the oil shortage and energy crisis which became apparent in late 1973. The oil shortage initiated a second study of selected power plants on the U.S. East Coast. In this second study[7,8] fuel conversion from oil to coal for selected boilers within specific plants is analyzed to evaluate the impact on SO_2 and particulate concentrations. Increased SO_2 emissions due to fuel conversions at 16 of 43 plants considered are estimated to result in concentrations from the plants alone which exceed the 24-hour NAAQS. Seven of the plant conversions are estimated to result in concentrations from the plant alone which exceed the 24-hour particulate NAAQS. The analysis indicates that in some cases partial conversion from oil to coal at selected power plants appears to be a viable option for alleviating the East Coast oil shortage.

Studies of Power Plants in 128 AQCRs

Further studies[9,10] of about 400 power plants distributed throughout the U.S. have been conducted in 1974 and 1975. The purpose is twofold: (1) to complete, on a national basis, analyses of the threat of large emitters of SO_2 to the NAAQS and (2) to add to the overall analysis of the power plant industry being conducted by governmental agencies and industry itself. Thus, a base for further analyses is developed and is available if additional decisions must be made concerning general EPA policy on compliance extensions or fuel use options for power plants. Of these 400 additional plants it is found that nearly 20 percent currently may exceed, by themselves, the 24-hour SO_2 air quality standards.

Evaluation of Model

Validation Studies

To determine the validity and overall accuracy of the Single Source Model, validation studies have been performed for the Canal, Paradise, Philo, Stuart and Muskingum River power plants. The Canal Plant[11] is located in Massachusetts along Cape Cod Bay. The Paradise Plant[12,13] is located in Western Kentucky. The other three plants are located in Southern

Ohio[14,15]. In all cases, hourly variations in SO_2 emissions are determined for each plant. These emissions are then used with hourly meteorological data which are representative of transport and dispersion in the vicinity of the plant. These data are input to the model and 1-hour, 3-hour, 24-hour and annual concentration estimates are made for the sites at which air quality monitors are located. The estimated and the observed concentrations are then subjected to several statistical comparisons. These include comparisons of highest and of second-highest concentrations and comparisons of observed and estimated concentration frequency distributions.

As shown in Table 1, the model generally tends to underestimate the highest and the second-highest 24-hour average concentrations. This is also true for 3-hour average concentrations. However, 1-hour averages are equally divided between overestimates and underestimates. In cases where surrounding terrain is nearly as high as the stack top (see the Philo Plant in Table 1), the model overestimates concentrations for all averaging times. It should be noted that most dispersion models comparable to the Single Source Model are not truly applicable in the vicinity of such significant terrain features.

Table 1. Comparison of Observed and Estimated Concentrations (μg/m³).

		3-Hour Average Concentrations				24-Hour Average Concentrations			
		2nd Highest		Highest		2nd Highest		Highest	
Plant	Sampling Station	O[a]	E[b]	O	E	O	E	O	E
Gavin	1	835	913	816	863	68	18	73	78
	2	855	174	818	178	50	8	66	41
	3	650	856	737	539	17	38	83	19
	4	875	827	836	478	61	8	75	18
Stuart	1	883	1372	857	1393	213	160	277	161
	2[c]	885	814	1018	884	12	75	113	88
	3	1057	585	1153	1562	181	81	215	122
	4	750	518	863	581	78	55	82	58
	5	855	873	965	1118	83	67	77	75
	6	960	595	1053	851	137	85	195	81
	7[c]	825	876	815	1006	65	73	77	129
Muskingum River	1	857	968	825	1082	131	87	176	87
	2	780	1309	776	1316	131	86	137	81
	3	800	877	1178	853	105	73	227	78
	4	735	505	788	855	100	35	115	87
Philo	1	823	1225	861	1030	133	133	183	167
	2	730	87	861	1080	87	88	118	188
	3	705	6068	817	6153	127	671	138	661
	4	865	1061	896	1581	80	189	160	231
	5	875	1273	873	1386	97	222	58	139
	6	868	2068	895	2092	161	362	189	358

[a] Observed concentrations with subtracted background.
[b] Estimated concentration.
[c] Samplers were in operation for less than ¾ of the year.

In the comparison of observed and estimated frequency distributions, disparate results are found. There is considerable variation in comparisons from site-to-site and plant-to-plant. However, agreement improves for frequency distributions which include all monitoring sites around a particular plant. As shown in Figure 1, all but the few highest and lowest concentration percentiles are accurately estimated for the distributions which include all sites.

Until further studies become available, it may be concluded from these validation studies that the Single Source Model is generally accurate within a factor of two. This is not surprising since this accuracy is widely accepted for such point source models. However, an important element is identification of the tendency to underestimate, rather than overestimate, concentrations for averaging times associated with NAAQS. This tendency undercuts the position of those who contend that such models are overly conservative when used in determining emission control requirements. It also places an added burden on pollution control officials to ensure that an environmental threat is not understated.

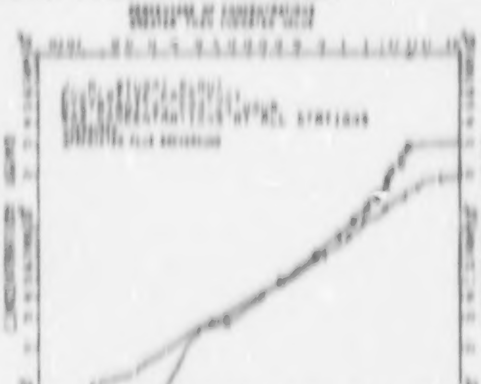

Figure 1. Stuart Plant Cumulative Frequency Distribution for 24-Hour SO_2 Concentrations at All Stations.

Sensitivity Analysis

To further understanding of the behavior of the Single Source Model, a sensitivity analysis[16] has been conducted. Specifically, this analysis examines the impact of variations or errors in the input data on the concentration estimates produced by the model. Thus, it identifies the model parameters which have the greatest influence on concentration estimates.

In the analysis the incremental change in predicted concentration is determined for an incremental change in input. A case study approach is used with the three Ohio power plants noted above. The analysis is limited to the maximum estimated 24-hour concentration, since this is generally considered to be the most important averaging time for power plants with regard to primary air quality standards.

Both source parameters and meteorological parameters are considered. The source parameters are (1) stack height, diameter, gas exit velocity, and gas exit temperature, (2) emission rate and its monthly variation and (3) terrain adjustment. The meteorological parameters considered are mixing height, wind speed, ambient temperature and stability class. With the exception of stability class, each parameter is varied by a factor of ± 5, ± 10, and ± 25 percent while all other parameters are held constant.

From the analysis summarized in Tables 2 and 3, it is found that for sources with relatively short stacks, for example the Philo Plant which has stacks about 300 feet high, a percent change in any stack parameter results in at least that percent change in the maximum 24-hour concentration. For sources with relatively tall stacks, for example the Stuart Plant which has stacks about 800 feet high, a lack of such sensitivity is found. Stability class, a meteorological parameter, is found to be a highly sensitive factor for all plants since this parameter can take on only six discrete values. The importance of parameters such as wind speed and mixing height varies depending on the meteorological conditions that result in highest concentrations for a plant. In all cases, the percent change in the maximum 24-hour concentration is less than the percent change in these meteorological parameters. Tables 2 and 3 indicate percent changes in maximum 24-hour concentrations for positive variations in source and meteorological parameters. Comparable changes in concentration can also be shown for negative variations in these parameters.

Table 2. Percentage Change From Base Case--Maximum 24-Hour Concentrations Due to Variations in Source Related Parameters.

Percent Variation in Parameter	Muskingum River			Philo			Stuart		
Parameter	+5	+10	+25	+5	+10	+25	+5	+10	+25
Stack height (m)	-2	-5	-11	-6	-12	-27	-2	-5	-11
Stack temp (°K)	-4	-8	-17	-4	-8	-18	-2	-4	-7
Exit velocity (m/s)	-5	-9	-19	-6	-10	-21	-1	-3	-7
Stack diameter (m)	-11	-17	-30	-11	-20	-41	-3	-5	-15
Terrain Abv (m)	1	3	12	5	8	24	1	1	3
Emissions (gm/sec)	5	10	25	5	10	25	5	10	25

Table 3. Percentage Change From Base Case--Maximum 24-Hour Concentrations Due to Variations in Meteorological Parameters.

Percent Variation in Parameter	Muskingum River			Philo			Stuart		
Parameter	+5	+10	+25	+5	+10	+25	+5	+10	+25
Mixing height (m)	0	0	0	0	0	0	-2	-5	-11
Wind speed (m/s)	-1	-5	-9	-3	-7	-21	-2	-3	0
Ambient temp (°K)	1	2	6	1	2	3	1	2	5
Stability class*	-	-	43	-	-	80	-	-	47

*Raised by 1 Stability Class

The sensitivity of the maximum estimated concentrations to changes in meteorological data sets is also determined. Three data sets are used with each set of source data. Changes in maximum concentration from the base case which are shown in Table 4, range from an increase of nearly 50 percent to a decrease of almost 30 percent. Inherent in the change of maximum concentration are the effects of the wind direction and the variability of wind direction. These are not considered individually in the sensitivity analysis. However, wind direction and its variability, which are a function of the meteorological conditions peculiar to each data set, play a major role in the percent concentration changes shown in Table 4. This illustrates the importance of a meteorological data set which is as representative of transport and dispersion in the vicinity of the plant as possible.

As a result of this analysis it can be concluded that: (1) the sensitivity of model estimates to accuracy in the input parameters varies from source to source; (2) accuracy in the source parameters becomes more critical as the stack becomes shorter; (3) errors in individual meteorological parameters, with the exception of stability class, result in somewhat smaller errors in estimated concentrations; (4) the cumulative errors in meteorological parameters, which result from the use of data from an unrepresentative site, can cause substantial errors in estimated concentrations.

Table 4. Percentage Change From Base Case--Maximum 24-Hour Concentrations Due to Variations in the Meteorological Data Sets.

Surface/Upper Air Data (1)	Muskingum River	Philo	Stuart
Huntington/Huntington	-	-28.4	-13.6
Dayton/Dayton	47.8	-	20.4
Cincinnati/Dayton	11.6	-5.8	-

Model Improvement

As a result of the model validation and the sensitivity analysis, studies to improve the Single Source Model are being undertaken. Two specific areas under investigation are (1) the use of other stability classification and dispersion parameters which may allow better estimates of plume dilution and (2) the use of more precise information on the stack parameters which affect plume rise. Also, additional analyses are being undertaken to evaluate the accuracy of hourly concentration estimates for various meteorological regimes. The goal is to assess the need for better data inputs or more precise algorithms in the model. Based on these studies, improvements in the model will be considered.

Applications of Power Plant Studies

Limitations on the model and its application in the power plant studies have been noted. Even with these limitations the power plant studies are of value for use in generalized analyses which assess the overall effect of some plan of action for the utility industry. These studies have been used effectively in a number of energy/environmental policy considerations.

The Clean Fuels Policy is an EPA program to encourage some states to eliminate unnecessarily stringent control regulations in their SIPs and thereby alleviate the shortage of low sulfur fuel. The power plant studies demonstrated the potential usefulness of such a policy and helped to indicate those SIPs where unnecessarily stringent regulations might exist.

The power plant studies were used in early analyses of proposed oil-to-coal conversions. They were useful in indicating the types of sources which were good candidates for conversion and specifically indicated several plants that were poor candidates. These studies have been used for roughly assessing the allowable percent sulfur coal which could be used in oil-to-coal conversions required under the Energy Supply and Environmental Coordination Act. They will serve as a basis for more detailed subsequent analyses.

In the development of EPA policy on tall stacks and meteorological control systems, the power plant studies were used frequently. They were used to analyze alternatives for limitations on stack height increases. They allowed the frequency and amount of emission reductions that would be required by meteorological control systems to be compared, for various categories of power plants, to permanent control requirements.

The power plant studies have been the basis for analyses in support of a viable SO_2 control strategy for Ohio. They were used as justification for existing regulations in the 1974 Ohio SO_2 hearings. They were used as an initial base in developing EPA Region V's current proposed regulations for Ohio[17]. They have also been used by Region IV in the development and revision of SIP, applicable to power plants located in the Southeastern United States.

Industry has used the power plant studies in statements[18] to the U.S. Congress on options for control of SO_2. These studies have also been used in evaluating the impact of proposed legislation to prevent significant deterioration of air quality.

Based on the demand for the reports resulting from such power plant studies, it is logical to conclude that other regulatory agencies and industrial groups are using these studies. In most cases, they are being extended by more detailed analyses. It appears that these studies will continue to play an important role in the development of regional and national environmental policies which affect utility power plants.

Acknowledgments

The authors wish to recognize the major contributions of their co-workers to these power plant studies. Major contributions were made by C. Barrett, W. Freas and R. Lee under the overall direction of H. Slater. Special recognition is also due to those individuals who performed the bulk of the work under contract to EPA. These include: P. Morgenstern and L. Morgenstern of Walden Research Division of Abcor, Inc., R. Koch of GEOMET, Inc.; and M. Mills and R. Stern of GCA Corporation. Thanks are also due to Mrs. B. Stroud who diligently prepared this manuscript.

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APPENDIX E

SENSITIVITY ANALYSIS OF THE SINGLE SOURCE (CRSTER) MODEL

by

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*On assignment from National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

SENSITIVITY ANALYSIS OF THE SINGLE SOURCE MODEL

Introduction

The purpose of this paper is to describe a sensitivity analysis of the Single Source (CRSTER) Model,[1] a model which has been used extensively by EPA to estimate the air quality impact of fossil fueled steam-electric power plants and selected industrial emission sources.

The question of model "validity" or "reasonableness" is addressed in some recent validation studies of the model for selected power plants.[2,3] A sensitivity analysis of the model provides the natural complement to these validation studies. Whereas a validation study assesses the impact of model formulation on calculated concentrations, a sensitivity analysis takes the model formulation as given and examines the impact of errors in the input data on the model calculated concentrations. The objective of a sensitivity analysis, therefore, is to identify the critical model input parameters--those variables which have the greatest influence on model predictions. Knowing the critical model parameters assists the model user in assigning proper priorities in the data collection and quality assurance procedures and in understanding the complex interactions within the model.

In order to complement the model validation studies, a case study approach is selected which models the same three Ohio power plants, Muskingum River, Philo, and J. M. Stuart.

Model Description

The dispersion model is a Gaussian plume model which calculates hourly and daily SO_2 concentrations for an array of 180 receptor locations, calculates maximum daily SO_2 concentrations for a year, and identifies the meteorological conditions associated with these maxima.

A ground plane displacement procedure is used in the model to simulate the effect of elevated terrain in the vicinity of the plant sites. This procedure consists of adjusting (decreasing) the height of each plume by an amount equal to the difference in elevation between the plant site and the average surrounding terrain.

An annual average SO_2 source strength and monthly variation factors must be specified.

Meteorological inputs to the model consist of hourly surface observations of wind speed, wind direction sector, temperature, total cloud cover, and twice daily mixing heights. The data are input into a preprocessor program which in turn writes a tape containing hourly values of stability index, mixing height, temperature, wind speed, flow vector (wind direction plus 180°), and randomized flow vector. The randomized flow vector is equal to the flow vector minus four degrees plus a random number between 0 and 9 degrees. The preprocessor output tape is read by the Single Source Model which performs the actual concentration calculations.

Plant Descriptions

The physical characteristics of each plant listed in Table 1 are those reported in the 1973 Federal Power Commission (FPC) Form 67, "Steam-Electric Plant Air and Water Quality Control Data for the year ended December 31, 1973."

Some of the stack heights listed below for the Philo and Muskingum plants differ from those reported in the referenced validation study.[3] It has been determined that modifications/replacement of some of the stacks at these plants are not reported in the 1973 FPC data. The stack heights listed in the validation study represent the current plant configuration (these values were obtained directly from the utility), whereas the stack heights in the present analysis reflect plant configuration prior to 1973.

Source Data

The source strength and monthly variation factors are calculated from data contained in the 1973 FPC Form 67. The data used in the calculations consists of the monthly fuel consumption and average sulfur content data. The values for the source strengths and monthly variation factors are listed for each plant in Table 2.

The adjustments for elevated terrain in the vicinity of each plant are those used in previous modeling studies of these plants.[4] The terrain adjustments, which represent the difference in elevation between the plant sites and the average of the surrounding terrain, are forty-nine meters for Muskingum River, thirty meters for Philo, and sixty-seven meters for Stuart.

TABLE 1. PLANT CHARACTERISTICS

Characteristic		Plant							
		Muskingum River				Philo			Stuart
		Stack 1	Stack 2	Stack 3	Stack 5	Stack 4	Stack 5	Stack 6	Stack 1-3
Stack	Height (m)	91	91	127	251	46	46	55	244
	Diameter (m)	4.5	4.5	6.8	7.7	5.7	4.3	2.8	8.8
	Velocity (m/s)	15.8	15.6	22.3	16.8	8.3	10.1	20.9	23.2
	Temperature (°K)	430	431	416	420	458	458	431	175
Number of Boilers per stack		1	1	2	1	2	2	1	1

Source: 1973 FPC Form 67

TABLE 2. PLANT EMISSIONS DATA

Source Parameter	PLANT									
	Muskingum River				Philo			Stuart		
	Stack 1	Stack 2	Stack 3	Stack 5	Stack 4	Stack 5	Stack 6	Stack 1	Stack 2	Stack 3
Source Strength (g/s)	1808	1614	2952	6025	586	552	891	1381	1261	1559
Monthly Factors:	All Stacks				All Stacks			All Stacks		
Jan.-June	1.04 .90 .92 .90 1.04 .96				.97 1.09 .86 .87 1.06 1.09			.92 .95 .79 .77 .79 1.0		
July-Dec.	1.06 1.03 1.13 .78 1.10 1.04				.97 1.02 .96 1.08 1.10 .96			1.11 1.17 1.06 1.17 1.10 1.1		

Source: 1973 FPC Form 67

Meteorological Data

The sources for the meteorological data used in this analysis are listed below.

Table 3. METEOROLOGICAL STATIONS

Plant	Surface Observations Airport	Upper Air Data Airport	Year
Muskingum	Huntington, W. Va.	Huntington, W. Va.	1964
Philo	Columbus, Ohio	Dayton, Ohio	1964
J. M. Stuart	Cincinnati, Ohio	Dayton, Ohio	1964

Methodology

Model sensitivity is defined as the partial derivative of the calculated concentration with respect to the parameter, p, evaluated at some value for p. That is,

$$\left.\frac{\partial \chi}{\partial p}\right|_{p = p_o}$$

For the purposes of numerical simulations, model sensitivity may be defined as "the incremental change in the calculated concentration resulting from the incremental change in input." These two definitions suggest the general approaches available for conducting a sensitivity analysis, analytical and numerical. Either method may be used to investigate both aspects of model sensitivity: the sensitivity of model predictions to (1) variations in the magnitude of each of the input variables and (2) the collective variations in all the input variables.

Because of the complex interactions of the meteorological and source variables found in this particular model, it is not possible, nor desirable, to examine the model sensitivities analytically. Analyses of this type have been performed for other Gaussian models, however.[5,6,7] This analysis concentrates on the first aspect of model sensitivity; that is, variations in the magnitude of the input variables related to both the source and the meteorology.

Source Related Parameters

The source related parameters examined in this analysis include:

1. Stack height (m)
2. Stack gas temperature (°C)
3. Stack gas exit velocity (m/s)
4. Stack diameter (m)
5. Emission rate (g/s)
6. Terrain adjustment (m)
7. Monthly variation factors

For the first six source-related parameters, systematic changes are introduced in each of the individual model parameters. Conceptually, this approach can be viewed as simulating events such as consistent instrument or technician bias. The actual numerical procedure consists of varying each of the initial source parameter values by factors of ±5, ±10 and ±25 percent of the initial value while holding all the other parameter values constant. For the sevensh parameter, the monthly variation factors, only the effect of no monthly variation (i.e. a constant emission rate for the year) is simulated. Interactions from changes in combinations of these parameters are not examined. In the analysis of the source parameters, computational savings are achieved by limiting the model calculations to the meteorology for the "worst 20 days" of the year.* These days are chosen on the basis of the calculated daily maximum 24-hour average concentrations from the "base case" simulations.

Meteorological Parameters

The meteorological parameters included in the analysis are:

1. mixing heights (m)
2. wind speeds (m/s)
3. ambient temperature (°C)
4. stability class
5. randomized flow vector
6. surface/upper air data sets

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*The phrase "worst 20 days" is used throughout this report to denote those days used in the source parameter analysis. The distribution of daily maximum 24-hour concentrations is examined for a "clean break" occurring near the top 20 days. The actual number of days selected varies from 22 days at Philo to 26 days at Stuart.

The analysis methodology for the first four meteorological parameters parallels that used for the source parameters. Systematic variations introduced in each of the meteorological parameters simulate the effect of errors resulting from factors such as observer and instrument bias or consistent trends in the meteorological variables. These variations are applied to each parameter individually; the effect of interaction is not examined.

In contrast to the analysis of the source parameters which uses only the meteorology from the "worst 20 days" in the simulations, the simulation procedure for the meteorological variables uses all 366 days of the year. This latter procedure eliminates the possibility of having the actual model calculated maximum concentration not fall on one of the "worst 20 days" due to the variations introduced in the meteorology related variables. The values of the parameters, wind speed, mixing height, and ambient temperature are biased by factors of ±5, ±10, and ±25 percent. Stability is biased by ±1 class, with the added restriction that stability class cannot be less than 1 or greater than 7.

The simulation procedures developed for the randomized flow vector include: (1) substituting a new random number generator (Univac's RANDU) and nine different starting numbers, and (2) eliminating the random number generator, i.e. using the average flow vector.

In an effort to assess the effect of changes in all of the meteorological variables, simulations are conducted for each plant using the surface/upper air data sets from the other two plants. The advantages of this ad hoc procedure over explicit numerical methods are (1) ease of operation, (2) minimal additional computer requirements, and (3) and identification of the effects of using different upper air and surface wind stations. With this procedure, however, it is not possible to explicitly identify the range of variation in each of the input variables.

Results

The results of the sensitivity analysis for the Single Source Model for the three Ohio plants are presented in tables, input/output response graphs, and cumulative frequency distribution plots. Primary emphasis is placed on the maximum 24-hour concentration of SO_2 in the graphical presentation of the results. This averaging time is the critical one for which power plants must meet primary National Ambient Air Quality Standards (NAAQS). The effects on the 1-hour and annual average concentrations are noted in the tables, however.

To provide a basis for comparison, the results from the base case simulations are summarized in Figure 1, the cumulative frequency distributions for the model calculated maximum 24-hour concentrations. As modeled, the Muskingum River plant has two short 91 meter stacks, one 131 meter stack, and one 251 meter stack. Unstable conditions are associated with the base case maximum 24-hour concentration at this plant. The three short stacks and elevated terrain considerations at the Philo plant yield a base case maximum 24-hour concentration which is associated with near neutral stability and persistent wind direction, about 11 hours with the winds within ±10 degrees of direction. At Stuart, a plant with three tall stacks (244 meters), the base case maximum 24-hour concentration is associated with unstable, light wind conditions with some limited mixing.

Source Related Parameters

The results of the sensitivity analysis for the source related parameters are summarized for all three plants in Tables 4 and 5 and input/output response curves, Figures 2 and 3. Apparent discontinuities in these response curves arise whenever, as the parameter values vary from their initial levels, the day associated with the maximum 24-hour concentration changes. Naturally, the meteorological conditions for this new maximum day differ somewhat from the original maximum day, thus producing a slightly different response.

An examination of the tables and graphs reveals, that for the Muskingum River and Philo plants, the maximum 24-hour concentrations are quite sensitive to changes in the values of the stack parameters, i.e. a unit change in the value of an individual stack parameter yields at least a unit change in the maximum 24-hour concentration. At the Stuart plant, however, a unit change in the value of any of the stack parameters yields less than a unit change in the maximum 24-hour concentration.

TABLE 8 PERCENTAGE CHANGE (%) IN BASE CASE MAXIMUM 24-HOUR CONCENTRATION DUE TO VARIATIONS IN SOURCE RELATED PARAMETERS

Percent error in value / Parameter	Muskingum River			Philo			Stuart		
	5	10	25	5	10	25	5	10	25
Stack height (m)	-2	-5	-11	-6	-12	-27	-2	-5	-11
Stack temp (°K)	-4	-8	-17	-4	-8	-18	-2	-4	-7
Exit velocity (m/s)	-5	-9	-18	-6	-10	-23	-2	-3	-7
Stack diameter (m)	-9	-17	-35	-11	-20	-41	-3	-7	-15
Terrain Adj (m)	1	2	12	5	9	26	1	1	3
Emissions (g/s)	5	10	25	5	10	25	5	10	25

Percent error in value / Parameter	Muskingum River			Philo			Stuart		
	-5	-10	-25	-5	-10	-25	-5	-10	-25
Stack height (m)	3	7	32	6	12	33	3	5	10
Stack temp (°K)	5	10	32	5	10	37	2	5	10
Exit velocity (m/s)	5	10	28	6	12	36	2	6	11
Stack diameter (m)	10	20	58	12	26	80	4	8	21
Terrain Adj (m)	-1	-2	-5	-4	-8	-20	-1	-1	-3
Emissions (g/s)	-5	-10	-25	-5	-10	-25	-5	-10	-25

TABLE 9 [illegible]

SIMULATION	MUSKINGUM RIVER			PHILO			STUART		
	Annual Mean	Max 24-hr	Max 3-hr	Annual Mean	Max 24-hr	Max 3-hr	Annual Mean	Max 24-hr	Max 3-hr
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

The data reveal that, for variations in stack diameter, the percentage change in the maximum 24-hour concentration is about double that found for exit gas velocity. The relationship between exit velocity and stack diameter is found in the model expression for volumetric flow rate:

$$VF = \alpha V_s D^2$$

Where α is a constant term, V_s is the stack gas exit velocity, and D is the stack diameter. Given this relationship and remembering the analytical definition of model sensitivity, i.e., the partial derivative of concentration with respect to the given parameter, one expects the sensitivity of the model calculated concentrations to variations in stack diameters to be twice that of stack gas exit velocity.

Except for the Philo plant, maximum 24-hour concentrations are not sensitive to variations in the value of the terrain adjustment, because the amount of the adjustment is quite small relative to the height of the stacks.

From the formulation of the model, we know that a unit change in emissions results in a unit change in the model calculated concentrations. Also, maximum concentrations occur on the same day as the base case maximum concentrations, only the concentration changes.

The seasonal factors simulate the effect of monthly variations in the emissions rate resulting from either differing load factors or varying sulfur content of the fuel. The effect of changing these factors, therefore, is to change the yearly distribution of emissions.

The effect of uniform emissions throughout the year, i.e. no seasonal variation, is shown in Table 5.

Meteorological Parameters

Tables 5 through 9 and Figures 4 through 8 summarize the sensitivity analysis results for the meteorological parameters.

The maximum 24-hour concentrations are very insensitive to variations in mixing heights at the Muskingum River and Philo plants. Using urban mixing heights rather than the base case rural mixing heights, the calculated maximum 24-hour concentration is unchanged at Philo, decreases by 2 percent at Stuart, and increases by 11 percent at Muskingum River as compared with the base case (Table 5).

At the Muskingum River and Philo plants, increasing the average wind speed produces higher 24-hour concentrations. However, at the Stuart plant which has three tall stacks, increasing (decreasing) the average wind speed decreases (increases) the maximum 24-hour concentration, i.e., the reverse of the relationship at the other two plants (Figure 5). The maximum concentration from a point source is affected by the wind speed in two ways, higher wind speeds dilute the plume and also reduce the plume rise, reducing the distance to the highest concentration. These two effects combine to produce the higher concentration at some critical wind speed. Thus, the maximum concentrations may either increase or decrease when wind speed increases.

[illegible]

[illegible]	[illegible]			[illegible]			[illegible]		
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[illegible]	[illegible]	—	[illegible]
[illegible]	[illegible]	[illegible]	—

Because the ambient temperatures are significantly lower than the stack gas temperatures, for a fixed change in ambient temperature there is small percentage change in plume buoyancy and thus a small percentage change in plume rise. Understandably, for the range of values considered in the analysis, the calculated maximum 24-hour concentrations are insensitive to variations in ambient temperature.

Lowering the stabilities by one class (one step more unstable) yields higher concentrations and raising stability by one class lowers concentrations. As Table 6 illustrates, the 24-hour concentrations are very sensitive to a bias of one stability class.

Using a different random number generator (RANDU) and nine different starting numbers, the greatest change from the base case maximum 24-hour concentration is +14% at Muskingum River, +0.8% at Philo, and -13% at Stuart (Table 5).

When the average flow vector is used in place of the randomized flow vector, the model calculated maximum 24-hour concentrations are 7% higher at Muskingum River, 10% higher at Philo, and 3% lower at Stuart (Table 5). Thus, the inclusion of the randomized flow vector in the model can either decrease or increase the calculated 24-hour concentrations. For example, when the wind blows directly toward the receptor, concentrations will always decrease when the randomized flow vector is added. However, if the wind blows 10° to the left of the receptor, the addition of the randomized flow vector can either decrease or increase the concentrations.

The sensitivity of the model calculated concentrations to the selection of individual surface/upper air data sets is determined by running the model for each plant with the meteorological data sets from the other two plants. Because two of these data sets share a common upper air station, it is also possible to factor out the effect of different surface wind stations on calculated concentrations.

The surface/upper air stations associated with each plant are Huntington/Huntington (HTG/HTG) at Muskingum River, Columbus/Dayton (CM/DAY) at Philo, and Cincinnati/Dayton (CVG/DAY) at Stuart.

Cumulative frequency distributions of the daily maximum 24-hour concentrations for all three data sets at each plant are presented in Figures 6 through 8. The shapes of all the distributions are quite similar except for some divergence at the upper percentile values.

Table 10 ranks the model calculated concentrations for the three averaging times from each of the meteorological data set simulations.

Table 10. MODEL CALCULATED CONCENTRATION RANKINGS

Surface/ Upper Air	Muskingum River Annual Avg.			Philo Annual Avg.			Stuart Annual Avg.		
		Max. 24-hr.	Max. 1-hr.		Max. 24-hr.	Max. 1-hr.		Max. 24-hr.	Max. 1-hr.
HTG/HTG	2	3	2	1	3	2	2	3	3
CMH/Day	3	1	3	3	1	3	3	1	1
CVG/Day	1	2	1	2	2	1	1	2	2

For all three plants, the highest 24-hour concentration and the lowest annual average are associated with the CMH/DAY data sets.

Comparing the results from the CMH/DAY and CVG/DAY data sets indicates that the Columbus surface wind data always give the maximum 24-hour concentration and the lowest annual average concentration. The maximum 24-hour concentration is a result of a single day with extremely strong wind persistence, about 11 hours with the winds within ±10 degrees of direction.

A further examination of the concentration rankings reveals that the HTG/HTG data always give the lowest value for the maximum 24-hour concentration. This appears to be due to a greater degree of fluctuations of the wind direction from hour to hour in the Huntington data.

Conclusions

As a result of this analysis it can be concluded that: (1) the sensitivity of model estimates to errors in the input parameters varies from source to source; (2) errors in the source parameters becomes more critical as the stack becomes shorter; (3) errors in individual meteorological parameters, with the exception of stability class, result in somewhat smaller errors in estimated concentrations than errors in source parameters; and (4) the cumulative errors in meteorological parameters which result from the use of data from an unrepresentative site, can cause substantial errors in estimated concentrations.

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7. Hilst, G. R., "The Sensitivities of Air Quality Predictions to Input Errors and Uncertainties," Proceedings of the Symposium on Multiple Source Urban Diffusion Models, Environmental Protection Agency, Research Triangle Park, N.C. (1970).

LIST OF FIGURES

1. Cumulative frequency distributions for model calculated max 24-hour concentrations at all three plants--base case.

2. Sensitivity of the yearly max 24-hour concentration to changes in stack gas exit velocity.

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4. Sensitivity of the yearly max 24-hour concentration to changes in mixing height.

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6. Cumulative frequency distributions of daily max 24-hour concentrations at Muskingum River--three meterological data sets.

7. Cumulative frequency distributions of daily max 24-hour concentrations at Philo--three meteorological data sets.

8. Cumulative frequency distributions of daily max 24-hour concentrations at Stuart--three meteorological data sets.

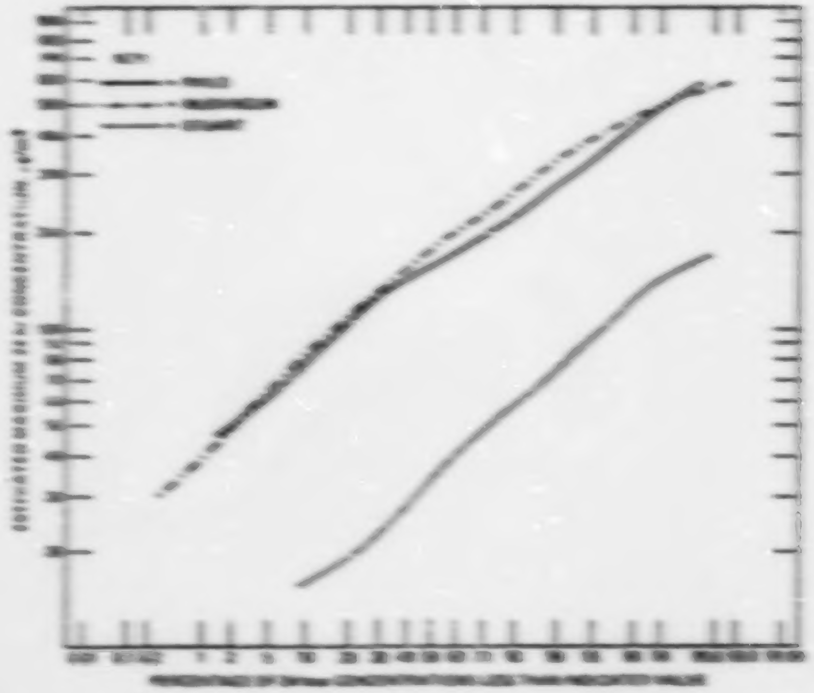


FIGURE 1. CUMULATIVE FREQUENCY DISTRIBUTIONS FOR MODEL CALCULATED MAX 24-HOUR CONCENTRATIONS AT ALL THREE PLANTS - BASE CASE

FIGURE [illegible]: SENSITIVITY OF THE YEARLY [illegible] 24-HOUR CONCENTRATION TO CHANGES IN [illegible]

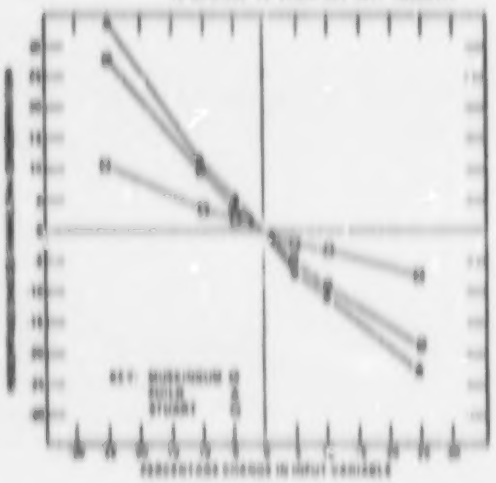


FIGURE [illegible]: SENSITIVITY OF THE YEARLY [illegible] 24-HOUR CONCENTRATION TO CHANGES IN [illegible]

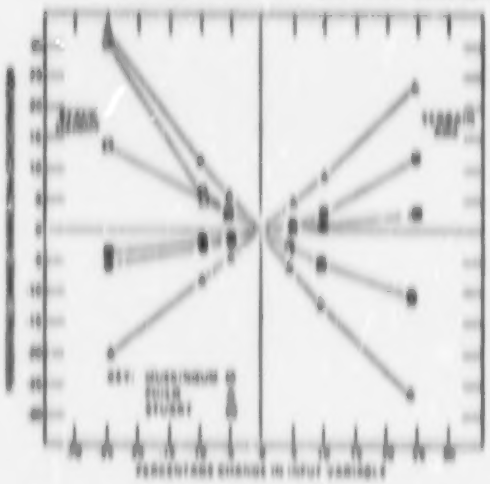


FIGURE [illegible]: SENSITIVITY OF THE YEARLY [illegible] 24-HOUR CONCENTRATION TO CHANGES IN [illegible]

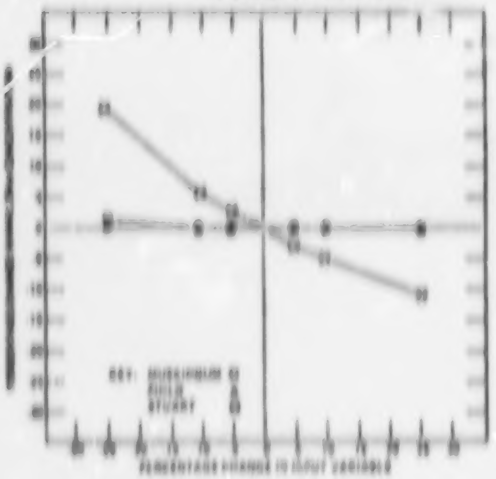
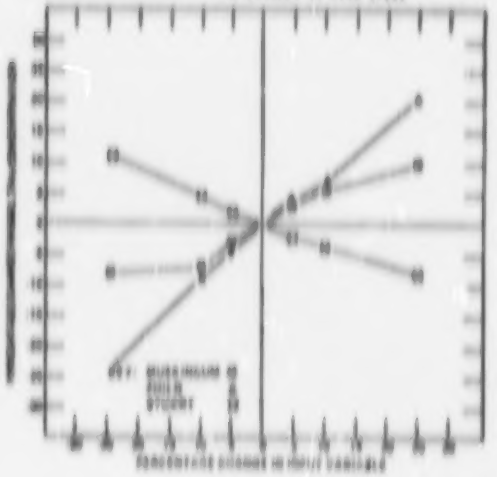


FIGURE [illegible]: SENSITIVITY OF THE YEARLY [illegible] 24-HOUR CONCENTRATION TO CHANGES IN [illegible]



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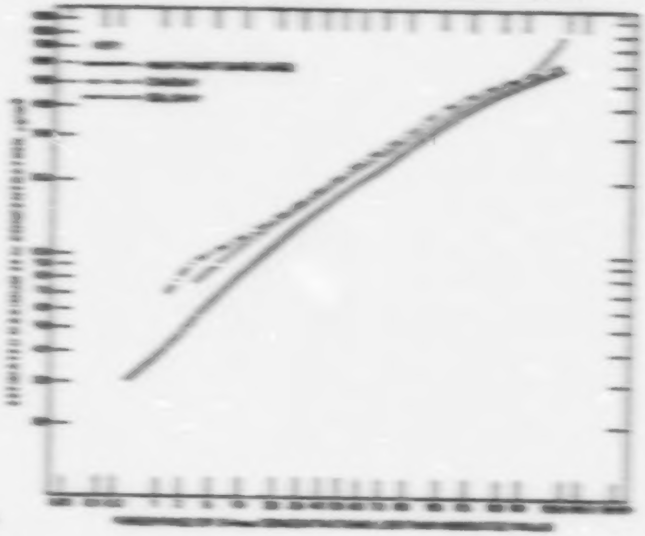

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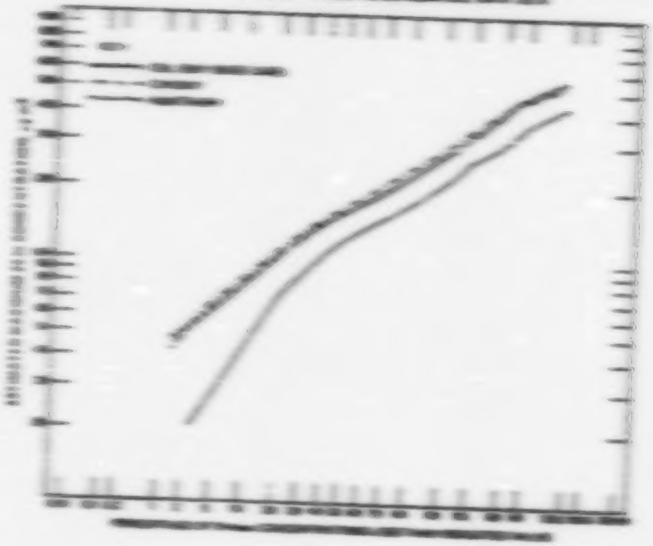

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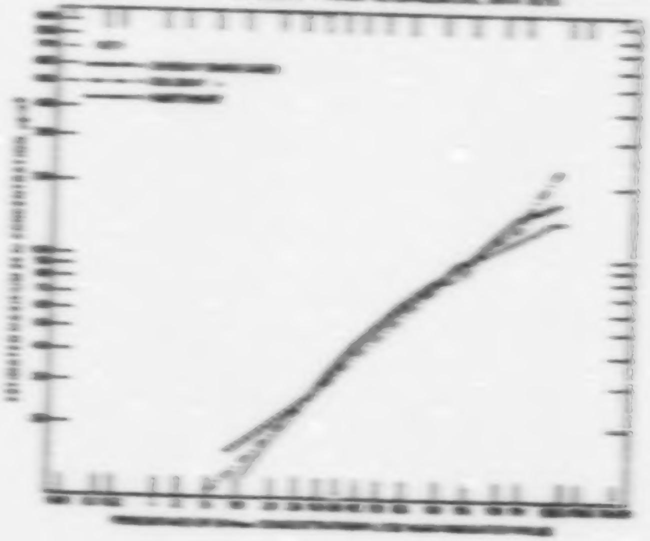

APPENDIX F

VALIDATION OF A SINGLE SOURCE DISPERSION MODEL

by

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U.S. Environmental Protection Agency

and

Michael T. Mills and Roger W. Stern
GCA Corporation

from

Proceedings of the Sixth International Technical Meeting
On Air Pollution Modeling and Its Application NATO/CCMS"
24-26 September 1975

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*On assignment from National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

1. INTRODUCTION

BACKGROUND

Estimates of SO_2 concentrations downwind from large power plants are urgently needed to guide environmental and energy related policy decisions. Most mathematical dispersion models for the prediction of SO_2 concentrations provide estimates over averaging times which are either very short (one hour or less) or very long (seasonal or annual). For example, the plume parameters given by Turner[1] and developed principally from earlier work of Pasquill, Cramer and Gifford are based on experimental data, most of which were collected for averaging times of 10 to 30 minutes. Power law relationships, by which concentrations from point sources are linked to averaging times, are generally considered to be valid only over averaging times that range from a few minutes to perhaps one or two hours. The National Ambient Air Quality Standards for SO_2 in the U. S., however, include an averaging time of 24 hours. A method currently favored for estimating 24-hour concentrations is to average concentrations that have been predicted for the component one-hour periods. To date, very few sets of field data have been available to test the adequacy of this estimation technique.

PURPOSE OF STUDY

The purpose of this paper is to describe validation studies of an Environmental Protection Agency dispersion model. The model was designed to estimate 1-hour and 24-hour ground-level concentrations caused by emissions of a single source. Emphasis is placed on the 24-hour value.

The analytical procedures are designed to parallel, to the extent practicable, those used by Klug[2] and Montgomery, et al.[3], in their analyses of TVA data.

MODEL DESCRIPTION

The EPA Single-Source Model (CRSTER) is a Gaussian dispersion model developed by the EPA Division of Meteorology. The procedure calculates maximum daily SO_2 concentrations for a year, identifies the meteorological conditions associated with the maxima, and calculates hourly and daily concentrations for an array of receptor locations. The concentrations are calculated for 180 receptor positions situated at each of 36 directions from the source and at five different distances. The model handles from 1 to 19 sources but assumes all are at the same physical location.

Meteorological inputs to the model consist of hourly surface observations of wind speed (knots), wind direction sector (tens of degrees), temperature (°F), total cloud cover (tenths), and twice daily mixing heights (meters). The format for these data is that used by the National Climatic Center for punched cards of hourly surface observations. The data are input into a preprocessor program which, in turn, writes a tape containing hourly values of stability index, mixing height, temperature, wind speed, flow vector (wind direction plus 180°), and randomized flow vector. The randomized flow vector is equal to the flow vector, plus a random number between -4 and +5 degrees. The randomization procedure prevents excessive concentrations in azimuths which are exact multiples of ten degrees. The preprocessor output tape is then read by the single source model which performs the actual concentration calculations.

The preprocessor program generates hourly mixing heights from the twice daily mixing height measurements according to the interpolation scheme for rural areas described in the Interim User's Guide[4]. Hourly stabilities are determined according to the system given by Turner[1] employing Pasquill's classification scheme with the addition of a stability class 7 (G) for which the assumption is made that the plume does not reach the ground. Wind speeds (u_0) measured at instrument height (h_0) (assumed 7 meters for most weather stations) are adjusted by means of a stability dependent power law ($u = u_0[h/h_0]^p$) to correspond to values one would expect at the stack top (h). Plume rise is calculated on an hourly basis using the method of Briggs[5,6,7]. If the plume rise calculation indicates that the plume height will be above the mixing layer, then a zero concentration is specified. If the plume height is below the top of the mixing layer, the presence of the top of the layer is accounted for by introducing image plumes (see Turner[1]) to satisfy the essentially zero flux conditions at ground level and at the top of the mixing layer.

Source strengths input to the single source model may posses various degrees of temporal resolution. In the seasonal version of the model, an annual average SO_2 source strength is specified along with monthly variation factors. In addition to the monthly factors, the diurnal version of the model employs hourly emission variation factors for each month of the year. A modified version of the model, used in this validation study, allows actual hourly source strengths to be utilized.

2. PLANT DESCRIPTIONS

CANAL PLANT

The Canal Plant and Surroundings

The Canal Plant is located on the south side of the Cape Cod Canal about 1.6 kilometers from the entrance on Cape Cod Bay (Fig. 1). The surrounding terrain is gently rolling with elevations generally below 60 meters above mean sea level. The highest elevations in the area are about 90 meters above sea level in the western end of the Cape. Most of the area is covered with scrub pine forests and low vegetation.

Data for the study were collected in 1971. During that year, the plant consisted of a single oil-fired unit with a generating capacity of 560 megawatts. The top of the stack was about 91 meters above grade and 5.6 meters in diameter. The main power plant structure to the north of the stack totally enclosed the turbine generator and boiler. The roofs of the turbine and boiler rooms were about 30 meters and 59 meters above grade respectively. Stack and boiler data are given in Table 1.

Overview of Monitoring Program

SO_2 concentrations were measured at four locations on a continuous basis with Ultragas SO_2 Analyzers manufactured in Germany by H. Wosthoff. These instruments measure sulfur dioxide by the increase in conductivity

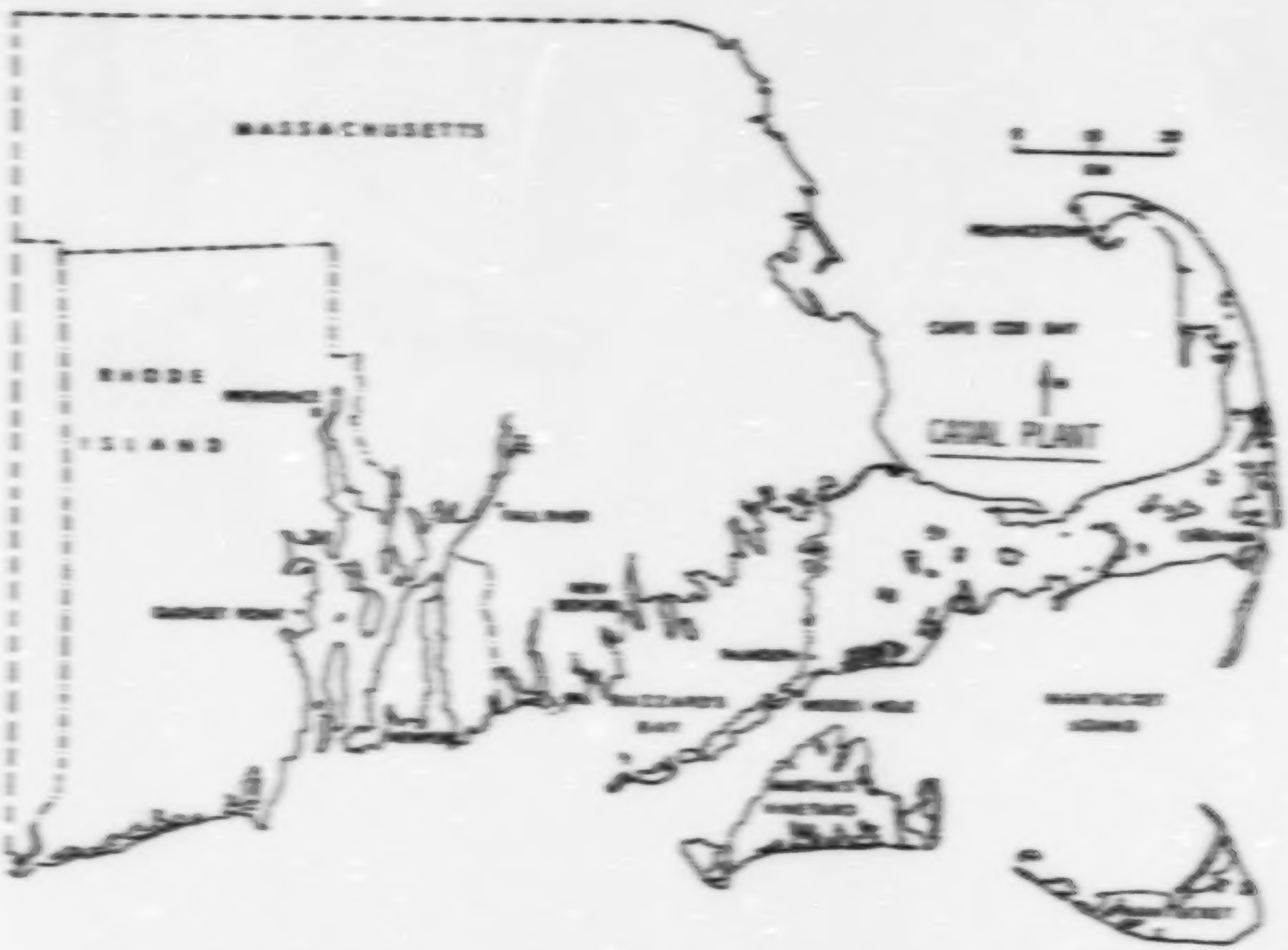
MASSACHUSETTS
RHODE ISLAND
CAPE COD BAY
CANAL PLANT

Figure 1. Map of eastern Massachusetts and Rhode Island showing location of the Canal Plant. Meteorological observations were used from Quonset Point Naval Air Station and Nantucket Island

Table 1. PLANT CHARACTERISTICS

	Plant						
	Stuart	**Muskingum**		**Philo**			**Gavel**
	Stacks	Stack	Stack	Stack	Stack	Stack	Stack
Characteristic	all four	1	2	4	5	6	1
Stack height (M)	244	251	251	81	81	84	91
diameter (M)	6.0	7.6	6.7	5.2	3.9	2.6	5.6
velocity (M/S)	22.2	28.5	24.8	4.5	7.7	28	-
temperature (°K)	373	430	425	458	468	433	-
Number of boilers per stack	1 each	4	1	2	2	1	1
Maximum generating capacity per stack (MW)	610	876	591	166	166	125	580
Average per stack (MW)	439	748	487	114	128	84	-
Plant total (MW)	2440	1467			457		580
Plant average (MW)	1318	1235			326		-

of an acidified hydrogen peroxide solution and have a full scale reading of 0.4 ppm. The instruments do not conform to the reference method for sulfur dioxide or to any of the specified equivalent methods[8]. They have, however, been extensively studied and one comparison noted a correlation coefficient of 0.99 with the West-Gaeke method[9]. The instruments used provide a continuous real-time chart trace and a tape printout giving date, time, and average concentration over consecutive 30 minute periods. The locations of the SO_2 monitors with respect to the Canal Plant are given in Figure 2 and Table 2.

Meteorological Data

Bendix-Friez Aerovanes were used to provide local wind speed and direction data. Through July 1971, the principal source of wind data was the Aerovane mounted on a 12.2 meter mast located on the 58.8 m boiler-room roof. After July 1971, wind data were obtained from a second Aerovane installed on a 44 meter tower near the top of Telegraph Hill, approximately 5 kilometers south-southeast of the Canal Plant. Wind data were used to identify the samplers not affected by the plant, for background determination, and for the dispersion modeling. Mixing heights were derived from the Nantucket Island Rawinsonde data.

STUART PLANT

Stuart Plant and Surroundings

The J. M. Stuart plant is located in Southwestern Ohio on the Ohio River, about nine kilometers southwest of Manchester, Ohio,

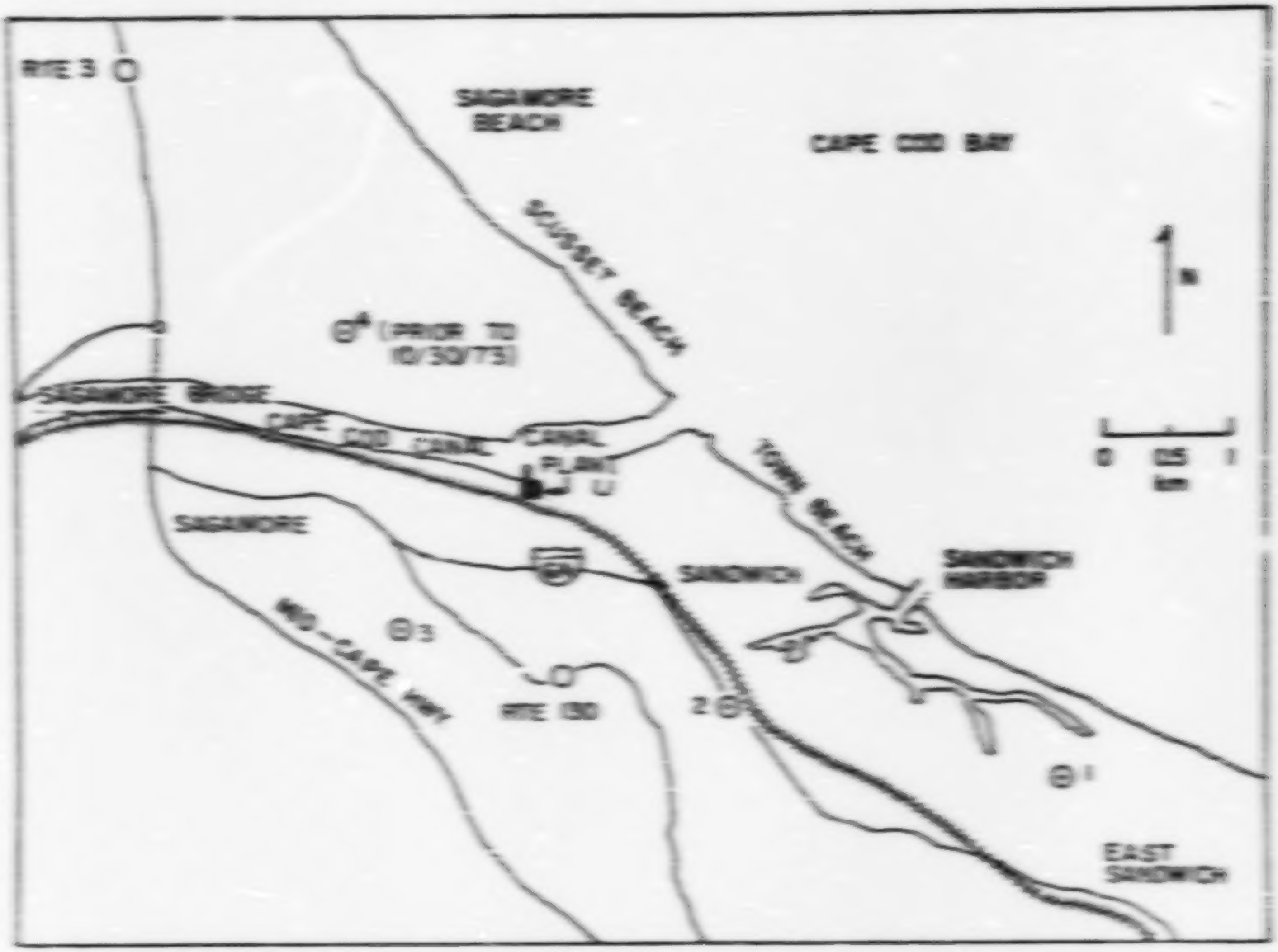
RTE 3
SAGAMORE BEACH
CAPE COD BAY
SCUSSET BEACH
N
⊖4 (PRIOR TO 10/30/73)
SAGAMORE BRIDGE
CAPE COD CANAL
CANAL PLANT
U
0
0.5
1
km
TOWN BEACH
SAGAMORE
SANDWICH
SANDWICH HARBOR
⊖3
MID-CAPE HWY
RTE 130
2 ⊖
⊖1
EAST SANDWICH

Figure 2. Sketch of the Canal Plant area showing the locations of the four automatic SO_2 stations by the symbol ⊖

Table 2. SULFUR DIOXIDE MONITOR STATIONS

Plant	Station No.	Station Name	Distance (km)	Bearing (degrees)	Elevation above stack base (m)
Canal	1		4.7	119	10
	2		2.3	138	6
	3		1.4	224	40
	4		2.0	312	20
	-	Top of stacks	-	-	91
Stuart	1	Boone	2.4	35	115
	2	Brudysville	6.6	15	85
	3	Bentonville	13.4	78	121
	4	Manchester	0.7	49	-7
	5	Maysville	3.8	279	-4
	6	Rectorville	8.4	156	115
	7	Somo	5.0	220	115
	-	Top of stacks	-	-	244
Muskingum	1	Beverly	5.3	140	64
	2	Hackney	4.3	40	82
	3	Rich Valley	8.3	35	101
	4	Caldwell	19.6	35	128
	-	Top of stacks	-	-	251
Philo	1	Philo	1.7	174	3
	2	Fox Run	4.0	168	2
	3	Irish Ridge	5.0	235	99
	4	Duncan Falls	1.3	343	12
	5	Salt Creek	6.0	25	26
	6	Indian Run	4.2	334	63
	-	Top of stacks	-	-	81

and four kilometers east of Maysville, Ohio (Figure 3). It is located near the center of the river valley. The ridges on either side of the valley are about 115 meters above the valley floor and 700 meters from the power plant. The 244-meter stacks rise 130 meters above the surrounding countryside. The data were collected during the one year period from January 1, 1973 to December 31, 1973. The plant consisted of four identical coal fired boilers with a capacity of 610 megawatts each. However, one boiler was under repair during the entire year so that the total generating capacity was only 1830 megawatts. The yearly average generating load was 1318 megawatts, or 72 percent of available capacity. Stack and boiler data are given on Table 1.

Overview of Monitoring Program

The monitoring network consisted of seven sulfur dioxide monitoring stations (Fig. 4 and Table 2). The instruments were electrolytic conductivity devices manufactured by Leeds & Northrup Company. The sample was obtained by passing ambient air, taken from five feet above ground level, through an absorption column along with an absorption solution. Data were taken continuously and listed every hour. Electrical calibration tests were performed weekly for zero and half-scale operations. Overall calibration tests were made every six months at 0.2 ppm using the permeation tube method whose accuracy is traceable to the U. S. Bureau of Standards.

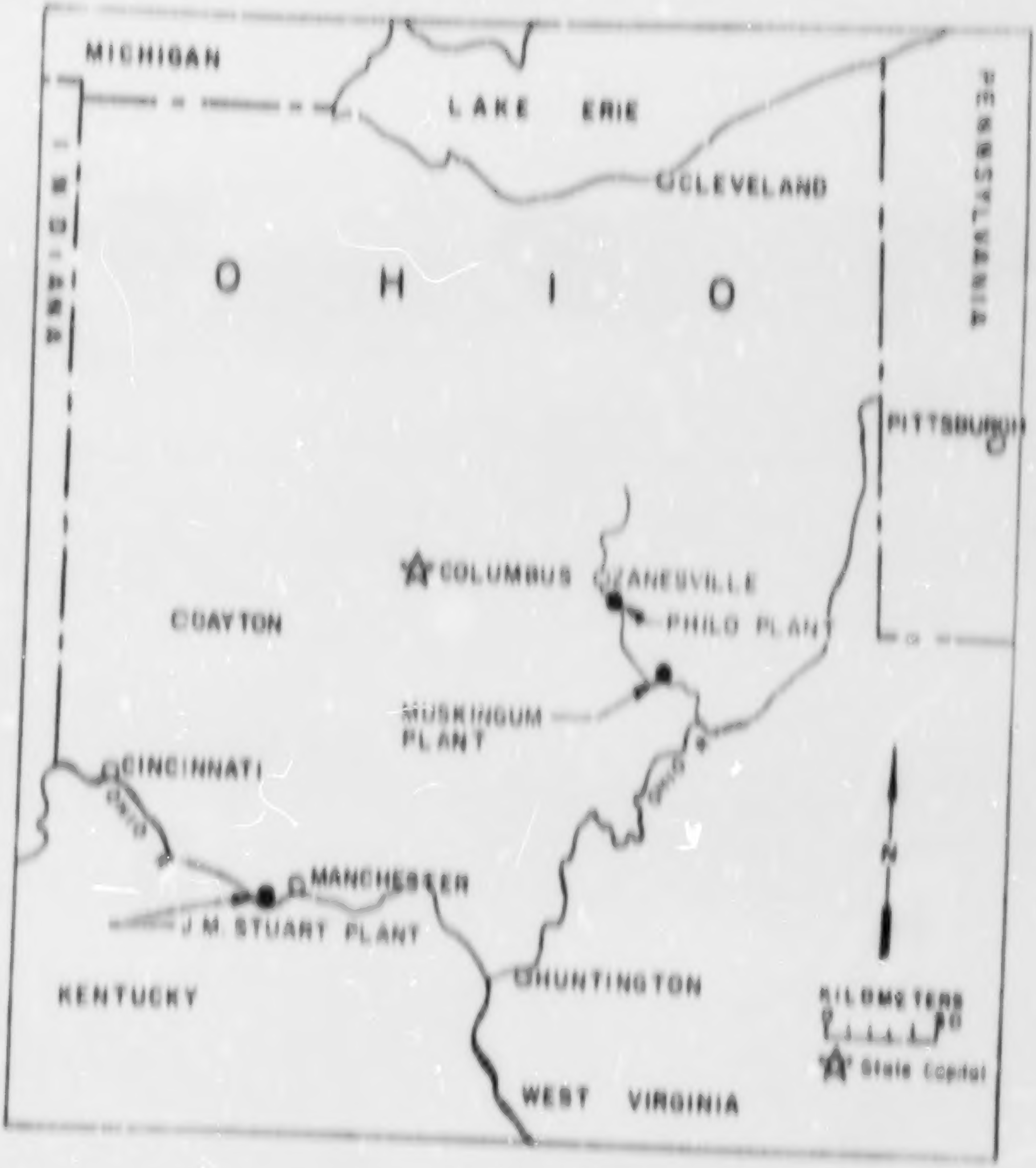
MICHIGAN
LAKE ERIE
CLEVELAND
INDIANA
PENNSYLVANIA
OHIO
PITTSBURGH
COLUMBUS
ZANESVILLE
PHILO PLANT
DAYTON
MUSKINGUM PLANT
CINCINNATI
OHIO R.
MANCHESTER
J.M. STUART PLANT
KENTUCKY
HUNTINGTON
WEST VIRGINIA
N
KILOMETERS
0
State Capital

Figure 3. Map of Ohio and surrounding states showing location of J. M. Stuart Plant, Philo Plant, and Muskingum River Plant

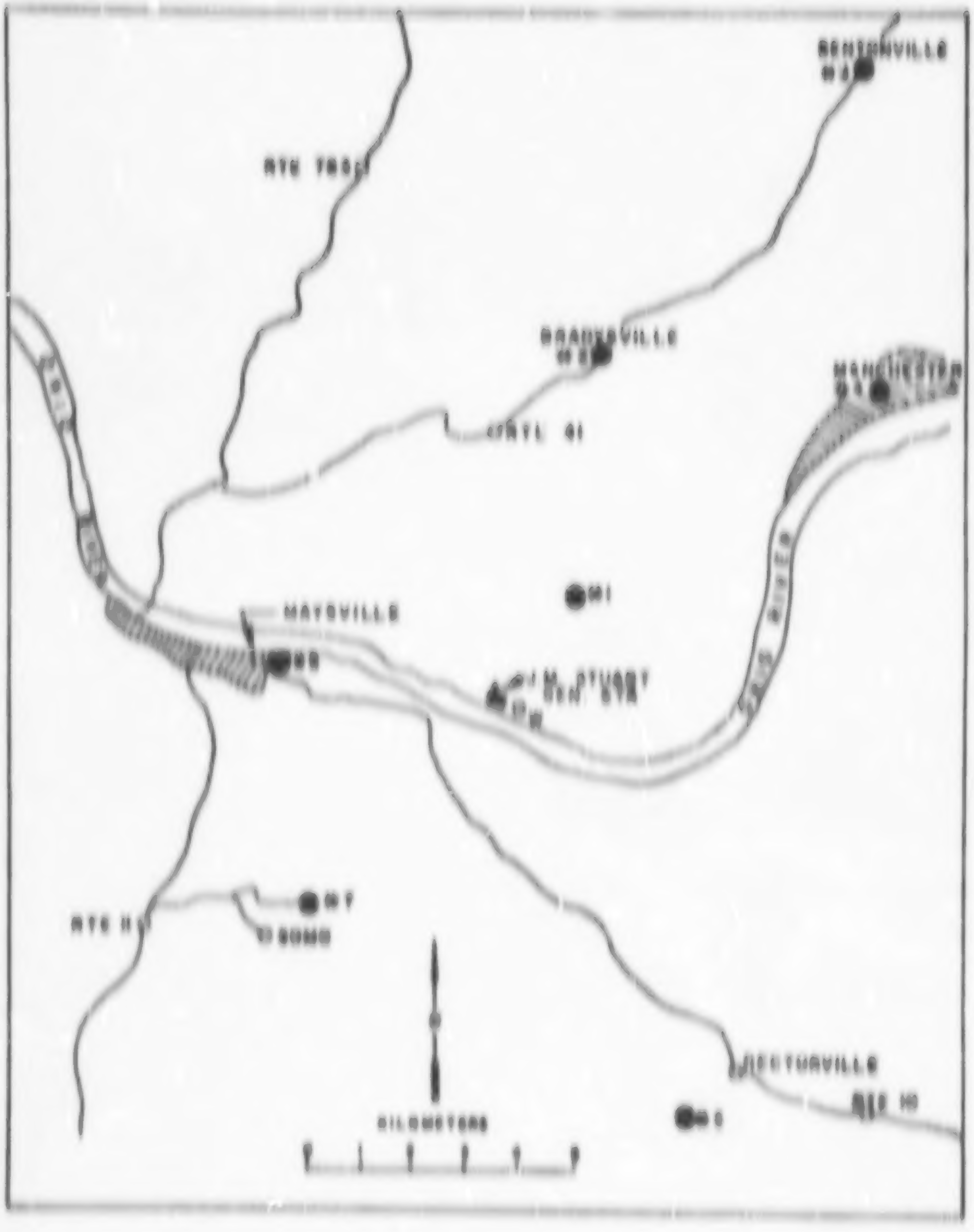
BENTONVILLE
BRADYSVILLE
MAYSVILLE
J.M. STUART GEN. STA.
OHIO RIVER
KILOMETERS

Figure 4. Sketch of the J. M. Stuart Plant area showing locations of seven automatic SO_2 monitoring stations

The monitor at Station 2 was moved to Station 4 on March 10, 1973, and the monitor at Station 7 was discontinued on June 17, 1973. Therefore, no data are available for Station 2 for nine months, Station 4 for three months, and Station 7 for six months. There were some additional hours of missing data due to loss of electrical power, periods of calibration and maintenance, and system failures.

Fuel Analysis

Each barge of coal from a specific vendor was sampled during the unloading process. All samples were analyzed. In the process of determining the caloric value of the coal by bomb calorimeter, the bomb washings were titrated using tetrahydroxyquionone (THQ) to determine the acid content which indicates the sulfur level. The procedure, the THQ colorimetric method, has been shown to be in agreement with the standard ASTM method. It is used as a typical procedure by the Dayton Power and Light Company and the American Electric Power System, and the Ohio Power Company.

Meteorological Data

The meteorological instrumentation at the J. M. Stuart Plant consisted of a Bendix-Friez wind speed and direction device mounted 40 meters above the ground on the coal stacking tower. The plant wind data were used to identify samplers not affected by the plant plume to aid in determining background. The meteorological data collected at the National Weather Service (NWS) Station at Cincinnati, Ohio were used in the model. Mixing heights were derived from rawinsonde data collected at the NWS station at Dayton, Ohio.

MUSKINGUM PLANT

Muskingum Plant and Surroundings

The Muskingum Plant is located in Southeastern Ohio, on the Muskingum River, about six kilometers northwest of the town of Beverly. Figure 5 indicates the location of the plant, the SO_2 monitoring sites, and the surrounding towns. The plant is in the river valley about 500 meters from the valley walls which rise about 75 meters above the valley floor. The two 251-meter stacks are 640 meters apart and extend about 185 meters above the surrounding terrain. During 1973 the plant consisted of five coal fired units with a total capacity of 1467 megawatts (Table 1).

Overview of the Muskingum Monitoring Program

Four sulfur dioxide monitoring stations made up the monitoring network (Fig. 5 and Table 2). The monitoring stations were established in 1969 to monitor the ambient changes when the new stacks were installed[10].

Meteorological Data

There were two wind monitoring stations. Both used Friez Aerovane wind speed and direction devices. One was located at Beverly mounted 33 meters above ground, and the other at the Hackney SO_2 monitoring

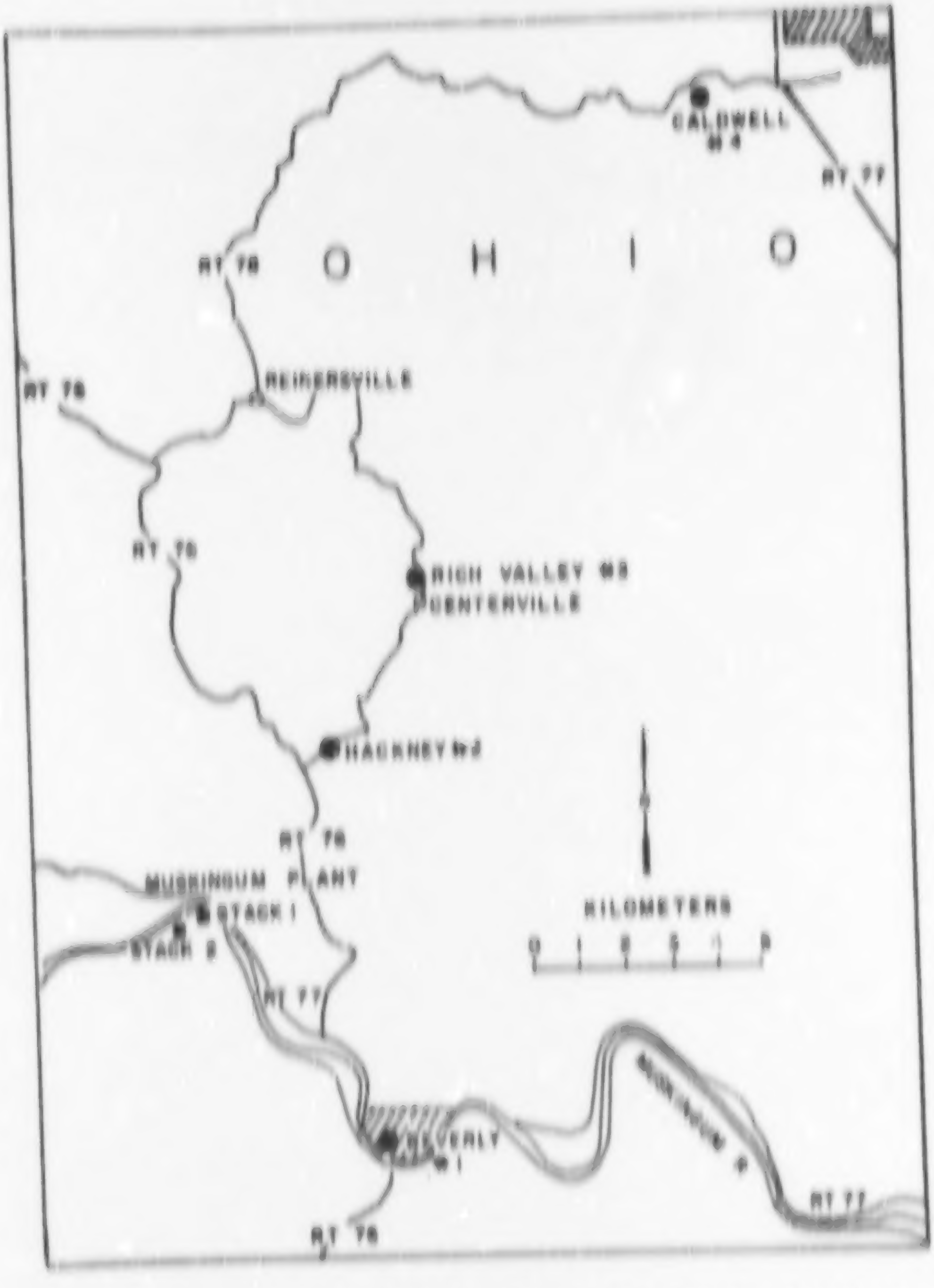
CALDWELL
#4
RT 77
O H I O
RT 78
RT 78
REINERSVILLE
RT 78
RICH VALLEY #3
CENTERVILLE
HACKNEY #2
RT 78
MUSKINGUM PLANT
STACK 1
STACK 2
RT 77
KILOMETERS
0 1 2 3 4 5
BEVERLY
#1
MUSKINGUM R
RT 77
RT 78

Figure 5. Sketch of the Muskingum Plant area showing locations of four automatic SO_2 monitoring stations

station, on a 22-meter mount. The data from Hackney were used for selecting the "background" stations, but Beverly data were used when the Hackney data were missing.

Weather data used in the modeling were obtained from upper air and surface data collected at the NWS station at Huntington, West Virginia. (See Figure 3).

PHILO PLANT

Philo Plant Description

The Philo plant is a 457 megawatt facility located in eastern Ohio on the Muskingum River in the town of Philo, about 11 kilometers to the southeast of Zanesville, Ohio (Figs. 3 and 6). The plant is roughly 500 meters from the valley walls to the east and west, although the valley widens to the north. The three stacks are approximately 82 meters high and rise about 10 meters above the surrounding terrain. During 1974, the period of this study, the plant consisted of five coal-fired boilers feeding into three stacks (Table 1).

Overview of the Philo Monitoring Program

The monitoring system in 1974 was made up of six Meloy continuous SO_2 samplers, located as shown in Fig. 6 and Table 2. The monitoring system maintenance and data acquisition were performed by the Environmental Research and Technology Company in Lexington, Mass. The instruments were calibrated every six months in Lexington and zeroed every night by computer.

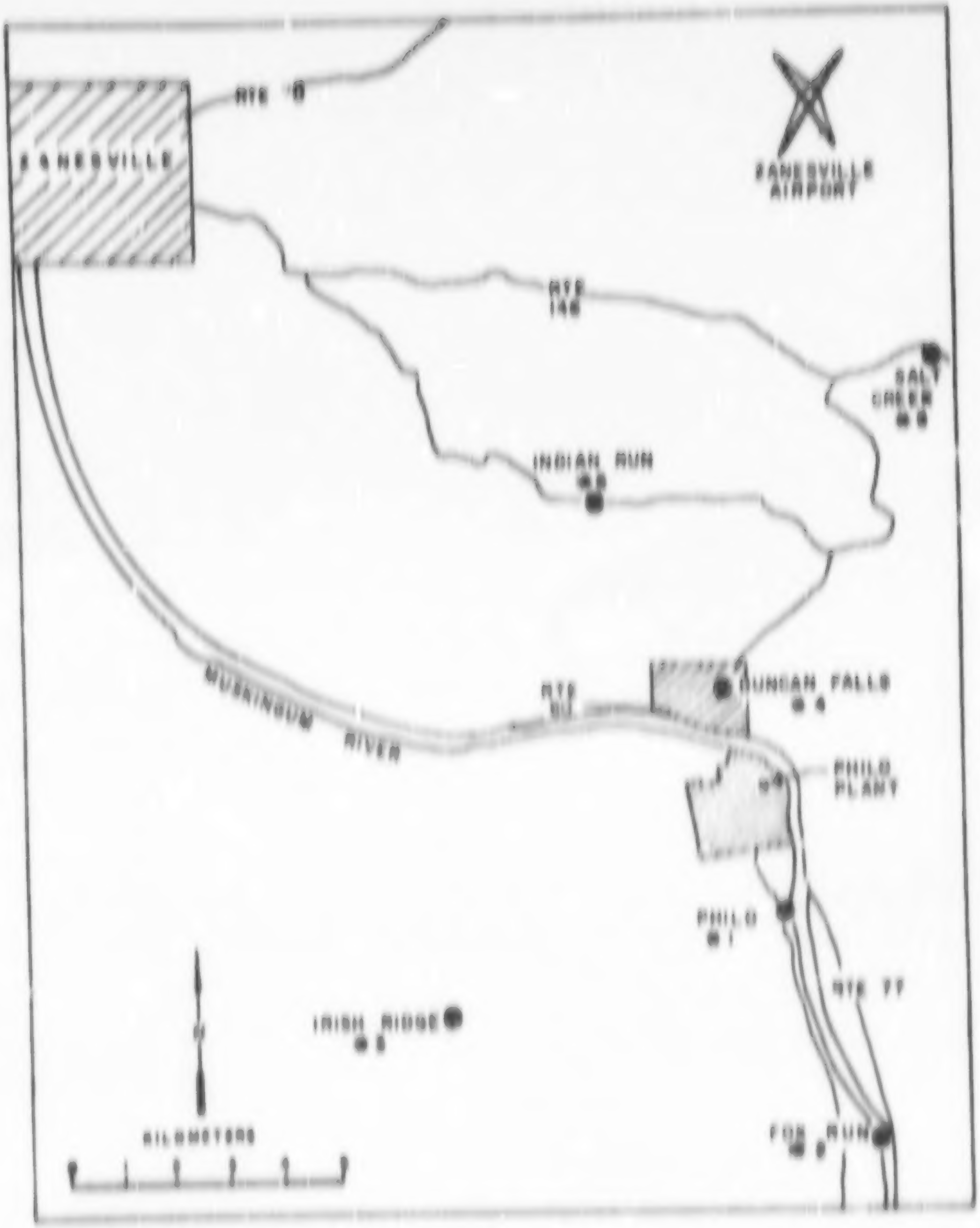
ZANESVILLE
RTE 70
ZANESVILLE AIRPORT
RTE 146
SALT CREEK
#6
INDIAN RUN
#3
DUNCAN FALLS
#4
RTE 60
MUSKINGUM RIVER
PHILO PLANT
PHILO
#1
RTE 77
IRISH RIDGE
#5
FOX RUN
#2
N
KILOMETERS
0
1
2
3
4
5

Figure 6. Sketch of the Philo Plant area showing locations of six automatic SO_2 monitoring stations

Data were recorded for all of 1975 except for the following:

Station 1	First 91 days of year
Station 4	First 91 days of year
Station 6	Second 91 days of year

Meteorological Data

There were three meteorological stations:

1. Irish Ridge Upper - elevation 140 meters above plant base, (60 meters above ground). Measured wind speed and direction, temperature, and temperature difference between Irish Ridge Upper and Irish Ridge Lower.
2. Irish Ridge Lower - elevation 104 meters above plant base, (11 meters above ground). Measured wind speed and direction, and temperature.
3. Duncan Falls - elevation 14 meters above plant base, (6 meters above ground). Measured wind speed and direction.

The wind instruments were Climet Anemometers.

The winds from Irish Ridge Upper were used to determine which sites to use to estimate background. When Irish Ridge Upper data were missing, Irish Ridge Lower data were used. When that data were also missing, Duncan Falls data were used. Surface wind and stability data from the National Weather Service Station at Columbus, Ohio were used in the dispersion model. Mixing heights were derived from upper air data collected at Dayton, Ohio.

3. DATA PREPARATION AND PROCESSING

Meteorological Data

The sources of the meteorological data are shown on Table 3. Hourly surface observations from airport log sheets were keypunched on to cards.

Table 3

SOURCES OF METEOROLOGICAL DATA

Plant	Surface Observations Airport	Year	Upper Air Data Airport
Canal	Quonset Point, R. I.	1971	Chatham, Mass.
J. M. Stuart	Cincinnati, Ohio	1973	Dayton, Ohio
Muskingum	Huntington, W. Va.	1973	Huntington, W. Va.
Philo	Columbus, Ohio	1974	Dayton, Ohio

The surface observations included:

- station
- date and time
- ceiling height
- ambient temperature
- wind direction
- wind speed
- percent cloud cover

Table 4

AVERAGE MONTHLY PERCENT SULFUR CONTENT OF FUEL

Month	Canal	Stuart	Muskingum	Philo
January	2.0	1.8	4.9	3.9
February	1.9	1.6	4.8	4.6
March	2.1	1.8	4.8	4.7
April	1.9	1.7	4.5	4.4
May	2.1	1.8	4.7	3.3
June	2.1	1.6	5.0	3.2
July	2.1	1.5	4.7	2.6
August	2.0	1.5	4.7	3.1
September	1.9	1.5	4.3	3.2
October	0.9	1.5	4.6	2.4
November	1.0	1.8	4.5	2.6
December	0.9	2.1	4.4	3.7

Table 5. 1-HOUR CONCENTRATION DISTRIBUTION STATISTICS FOR MEASUREMENTS AND MODEL VALIDATION RUN ($\mu g/m^3$)

Plant	Sampling Station	Ninety-Fifth Percentile[a]		Ninety-ninth Percentile[a]		Second Highest		Highest	
		M[b]	P[c]	M	P	M	P	M	P
Canal	1	25	< 1	101	6	435	253	438	283
	2	14	< 1	72	< 1	563	174	618	179
	3	18	< 1	18	2	446	427	732	479
	4	15	< 1	31	< 1	575	81	638	377
Stuart	1	140	<10	270	400	685	1372	857	1393
	2[d]	80	<10	445	180	685	814	1014	948
	3	74	26	200	240	1022	565	1153	1022
	4	53	<10	160	130	750	515	883	641
	5	28	<10	80	<10	495	823	565	1219
	6	48	<10	135	120	980	595	1053	693
	7[d]	33	<10	102	30	325	976	435	1000
Muskingum R.	1	27	<10	150	160	857	980	925	1083
	2	57	<10	270	150	786	1304	786	1310
	3	130	<10	350	210	996	873	1179	933
	4	72	<10	200	160	735	465	786	645
Philo	1	60	<10	170	98	525	1295	893	1639
	2	37	<10	163	222	735	945	891	1059
	3	47	<10	164	920	745	4049	917	4593
	4	27	<10	190	88	665	1945	695	1981
	5	35	80	134	555	575	1279	675	1344
	6	116	20	253	650	565	2369	595	2482

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[a] Percentile values given in terms of cumulative percent of concentration less than given values.

[b] Measured concentrations with subtracted background.

[c] Predicted concentrations.

[d] Samplers were in operation for less than half the year. Data not included in subsequent analyses.

Table 6. 24 HOUR CONCENTRATION DISTRIBUTION STATISTICS FOR MEASUREMENTS AND MODEL VALIDATION RUN ($\mu g/m^3$)

Plant	Sampling Station	Ninety-Fifth Percentile[a]		Ninety-ninth Percentile[a]		Second Highest		Highest	
		M[b]	P[c]	M	P	M	P	M	P
Canal	1	32	4	52	14	66	16	75	29
	2	15	<1	28	6	36	9	46	11
	3	17	4	46	10	77	38	83	39
	4	15	<1	44	2	63	4	75	16
Stuart	1	83	55	245	120	259	149	277	161
	2[d]	46	28	160	52	63	75	159	98
	3	50	36	110	75	181	91	225	102
	4	40	24	63	41	79	45	83	49
	5	31	5	52	50	63	57	77	75
	6	42	21	135	46	147	65	195	83
	7[d]	45	23	69	60	69	73	77	120
Muskingum R.	1	32	32	100	69	133	81	170	97
	2	55	32	100	80	131	82	137	91
	3	90	31	130	58	165	73	227	74
	4	52	24	95	41	109	45	115	47
Philo	1	45	29	134	139	132	133	133	147
	2	35	39	60	69	67	86	110	104
	3	44	143	92	368	127	471	132	541
	4	41	47	60	111	62	165	158	220
	5	23	81	78	207	87	222	94	226
	6	65	107	121	217	121	282	138	356

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[a] Percentile values given in terms of cumulative percent of concentrations less than given values.

[b] Measured concentrations with subtracted background.

[c] Predicted concentration.

[d] Samplers were in operation for less than half the year. Data not included in subsequent analyses.

Plant Emission Data

The hourly emission rate of SO_2 was computed from the fuel consumption rate and the sulfur content of the fuel. The hourly fuel consumption rate of each of the boilers was summed to obtain the plant fuel consumption rate. The plant fuel rate was then multiplied by the sulfur content and an appropriate conversion factor to obtain the hourly sulfur dioxide emission rate from the plant.

Air Quality Data

The air quality data required for this study were the concentrations of sulfur dioxide (SO_2) attributable to the plant being studied. The samplers measured concentrations, not only from the plant being studied, but from other sources as well. The portion of the concentration due to those other sources is referred to as background in this study. Since there is no accurate way of knowing how much of the total concentration is due to the power plant, this portion of the concentration must be estimated.

The portion of the concentration due to the plant, for each hour, at each sampler, was estimated, first, by estimating the background concentration and, second, by subtracting the background concentration from the concentration measured at each sampler. One background concentration was assumed to be valid for all receptors for one hour. The background concentration was taken to be the average of the concentrations from all samplers that are not located with ± 45° of the downwind direction. The downwind direction is based on the wind direction recorded by the wind vane at the plant. When the wind observation indicated calm, or was missing, the last recorded wind direction was used, with one exception. This exception occurred when a sampler recorded a concentration greater than 0.1 ppm. In that case the downwind direction was taken as the direction from the plant to that sampler.

Quality Control

Particular attention was given to quality control. Emissions, air quality, and meteorological data were each keypunched with the date and time preceding the measured values. All punched cards were verified. A computer program was used to check for missing hours, cards out of chronological order, input data out of range, and unreasonable changes between consecutive data values. The keypunched data were read onto magnetic tape, with each record prefixed by a plant code to prevent the unlikely mixing of data from different plants. All programs which modified the data had internal checking routines to assure that the correct data was read. The output from each program was spot checked by manual calculations.

4. RESULTS OF THE MODEL VALIDATION

Figures 7 through 22 show log-normal plots of cumulative frequency distributions of (1) measured concentrations, (2) measured concentration minus the estimate of "background," and (3) the model-calculated concentration for the same location. Rather than presenting data for all the sampling stations, data are shown for two sites for each plant. In each case, the data presented are from sites where the model gave the best and the poorest predictions, respectively. Tables 5 and 6 show the measured and predicted concentrations at each sampler for selected points on the frequency distributions.

A comparison of the frequency distributions of the model calculations and the observed one-hour concentrations shows that the model predicts the upper percentile fairly well, but significantly under-predicts most of the remainder of the distribution. A similar effect occurs in the frequency distributions of the 24-hour concentrations. Part of the underprediction may be due to sampler errors, as Klug speculates[2], since many of the lower concentrations are measured near the threshold of the sensing device. Also, much of the low concentration end of the distribution does not represent pollution from the plant at all, but rather differences between the estimated background and the actual background at the sampler. For example, if three samplers upwind of the plant recorded concentrations 10, 20 and 24 $\mu g/m^3$, the "background" would be considered the average of the upwind stations, in this case 18 $\mu g/m^3$. This "background" is subtracted from each concentration recorded at that hour, so that, in this case, there is one negative concentration, and two positive concentrations of 2 and 6 $\mu g/m^3$, respectively. Corresponding model predictions would, quite correctly, be zero.

Not all the underprediction can be explained by the above hypotheses, however. Several sampling stations show large underpredictions for high observed concentrations. For example, on the frequency distribution of one-hour concentrations at the Muskingum River sampling station 3, the 99th percentile measured value is well over 200 $\mu g/m^3$, while the model prediction is on the order of 60 $\mu g/m^3$. As Mills, et al.[11] noted, an error of this size could occur if the actual stability differs from the stability as calculated by the computer program.

In the U.S.A., short term (24 hours or less) National Ambient Air Quality Standards, for SO_2 and particulates, are given in terms of concentrations "not to be exceeded more than once per year." Thus, the second highest concentrations are of concern. The ratios of the model prediction to the measured (less background) of the second highest one-hour concentrations range from .3 to 3.0, except for two Philo samplers where the ratios are 4.2 and 5.4. These two samplers were located at elevations 10 meters below and 10 meters above the stack tops, respectively. The geometric mean of the ratios is 1.2. The corresponding ratios for the 24-hour concentrations range from .2 to 2.7, except for one sampler at the Philo plant where the ratio is 3.7 and one at the Canal plant where the ratio is 0.06. The geometric mean of the ratios is 0.7.

The model tends to underpredict the 24-hour concentrations, and slightly overpredict the one-hour concentrations. The degree to which the model overpredicts or underpredicts is a strong function of the plant being studied. For example, at the Canal plant, the second highest one-hour concentrations are underpredicted at three of the four sites, while the corresponding 24-hour concentrations are underpredicted at all four sites. The ratios of predicted to measured concentrations (without background) at the Canal plant range from .3 to 1.0 for 1-hour concentrations, and from less than .1 to .5 for 24-hour concentrations, with geometric means of .6 and .2 respectively (Figure 7). At Philo, however, the second highest one-hour concentrations are overpredicted at all six sites, and the corresponding 24-hour concentrations at five of the six sites.

Table 7

Geometric Means of the Ratios of Predicted to Measured (less background) Second-Highest Concentrations

Plant	1-Hour	24-Hour
Canal	.60	.20
Stuart	.95	.59
Muskingum River	1.01	.51
Philo	2.79	2.06
All Plants	1.23	.68

The ratios of the predicted to measured concentrations range from 1.3 to 5.4 for one-hour concentrations, and from 1.0 to 3.7 for 24-hour concentrations. The geometric means of the ratios are 2.8 and 2.1 respectively.

At the Stuart and Muskingum River plants, the second-highest one-hour concentrations are underpredicted at about as many sites as they are overpredicted. The corresponding 24-hour concentrations are underpredicted at all 11 sites. The ratios of predicted to measured second highest one-hour concentrations range from .5 to 2.0 with a geometric mean of 1.0. The corresponding ratios for 24-hour concentrations range from 0.4 to 0.9, with a geometric mean of 0.6.

The correlation coefficients between the ratio of the predicted to measured (less background) and distance are given in Table 8. The negative correlations of the ratios of predicted to measured with distance indicates a tendency for the model to underpredict more at greater distances. The correlation is highly significant at Stuart, but not statistically significant at the other plants.

The negative correlations between the ratios and distances are consistent with theory[12] and observations[13] which indicate that beyond a few kilometers, the plume width should not be proportional to distance to the 0.9 power as used in this model, but some smaller power.

Table 8. CORRELATION COEFFICIENTS OF RATIOS (predicted/measured) TO DISTANCE

Averaging Time	Plant	Correlation	95% Confidence Interval	Significant to 5% Level
1	Canal	-.41	-.98 to .91	No
1	Stuart	-.91	-.994 to -.14	Significant to 1%
1	Muskingum R	-.78	-.995 to .72	No
1	Philo	.09	-.78 to .84	No
1	All Data	-.29	-.66 to .19	No
24	Canal	-.24	-.98 to .94	No
24	Stuart	-.56	-.97 to .64	No
24	Muskingum R.	-.82	-.996 to .67	No
24	Philo	.33	-.66 to .90	No
24	All Data	-.19	-.59 to .29	No

5. CONCLUSIONS

Based on the analyses of the performance of the Single Source model at four large power plants, several conclusions can be made.

The model predicts the upper percentile of the frequency distribution of one-hour concentrations and of the corresponding distributions of 24-hour concentrations acceptably well. Concentrations over the remainder of the frequency distributions are significantly underpredicted. Part of this underprediction is an apparent one, resulting from the technique used to estimate the concentrations. Another portion of the underprediction is probably due to measurement errors when concentrations are near the threshold level of the instrument. Obviously there are also uncertainties in specifying the appropriate wind direction, wind speed, and stability class.

The following specific conclusions are made.

- The second highest one-hour concentrations are predicted within a factor of 2.0 at two-thirds of the sampling sites. The geometric mean of the ratios of the model prediction to the measured (less background) for all sampling sites is 1.2. The most significant overpredictions occurred around the Philo plant, where the model is less likely to account properly for the terrain influences. These influences are very pronounced because the effluent is emitted from stacks which are little higher than the terrain features themselves.
- The second highest 24-hour concentrations tend to be underpredicted by the model, with the ratio of predicted concentration to measured concentration ranging from about .2 to 2.7 at about 90 percent of the sites.

- The degree to which the model over or underpredicts concentrations is strongly dependent on the factors relating to the plant and its surroundings. For example, at the Canal plant, the model significantly underpredicts the second highest one-hour concentrations at three sampling sites out of four, and the second highest 24-hour concentrations at all four sampling stations. At the Philo plant, however, the model overpredicts the second highest one-hour concentrations at all six sites, and the second highest 24-hour concentrations at five of the six sites. At Stuart and Muskingum River, the second highest one-hour concentrations are underpredicted at three sites out of five and two sites out of four, respectively. The corresponding 24-hour concentrations are underpredicted at all the Stuart sites, and three of the four Muskingum River sites.
- The model tends to underpredict at greater distances, a tendency which is highly significant at one plant. This is consistent with theory[12] and observation[13] in that, at greater distances, the plume width increases with distance to a power rather smaller than the 0.9 power as is assumed in this model.

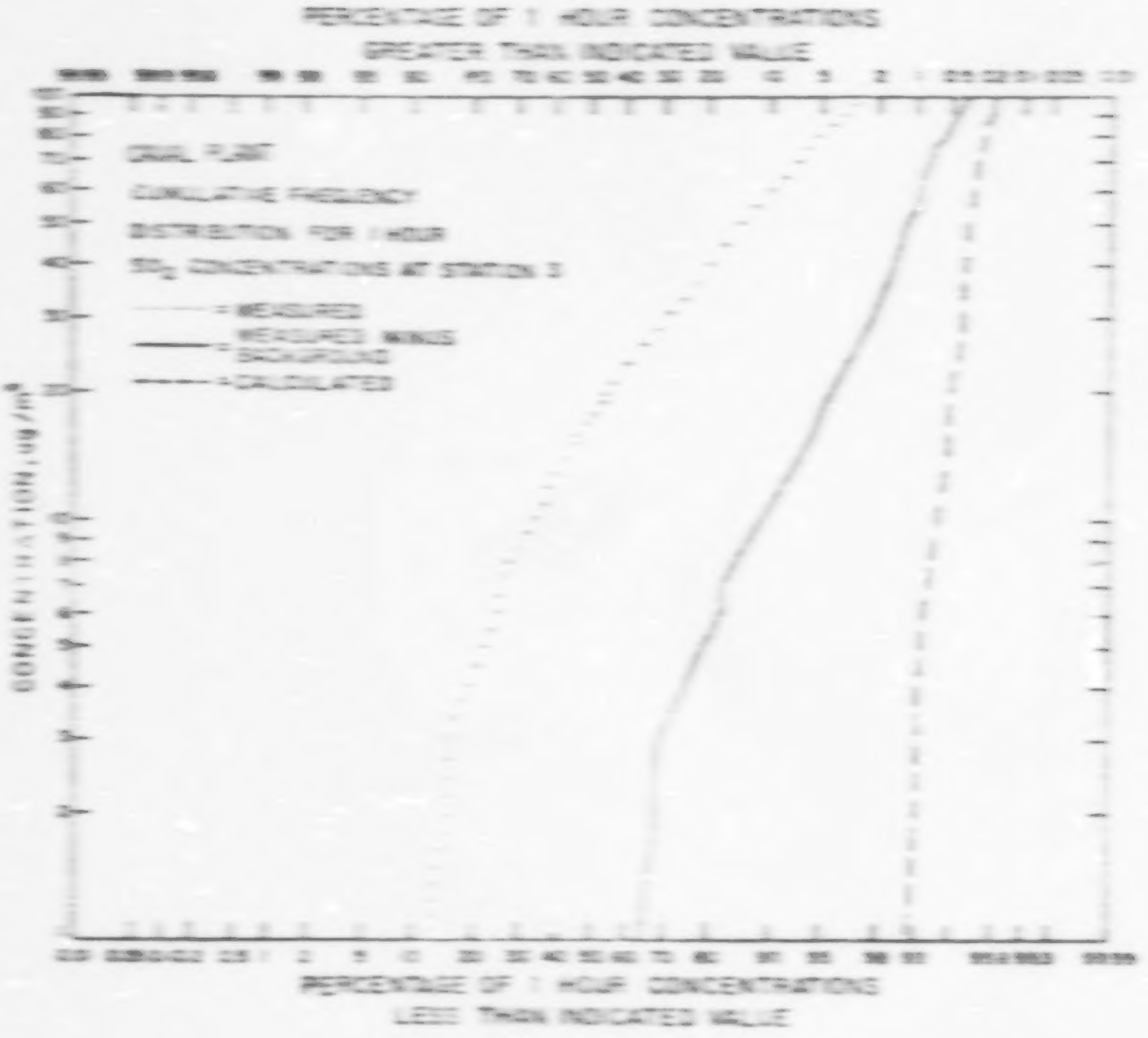

Figure [illegible]. Cumulative frequency distributions for 1 hour SO_2 concentrations at station 3

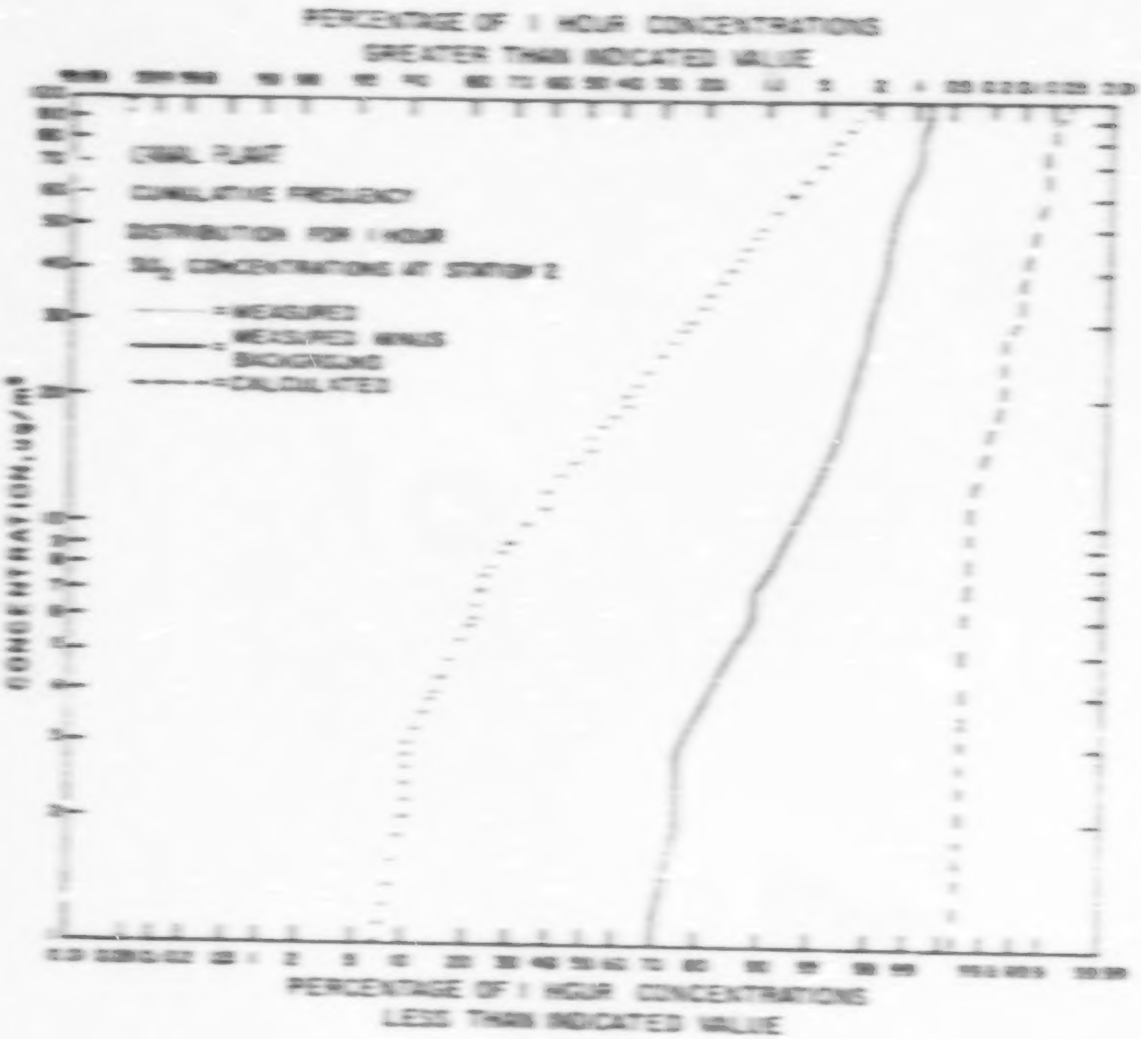

Figure 8. Cumulative frequency distributions for 1 hour SO_2 concentrations at station 2

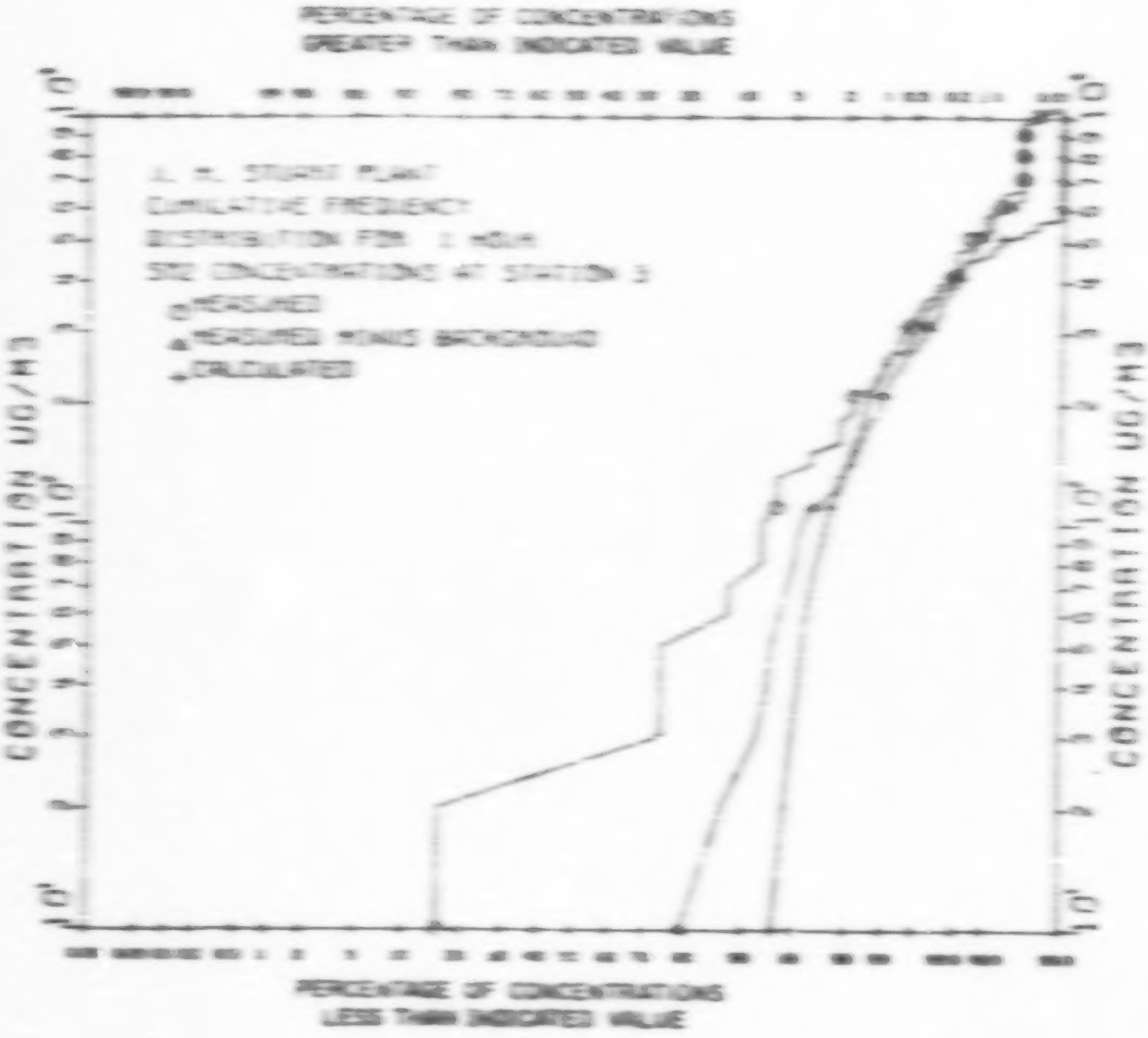

Figure 8. J. M. Stuart plant cumulative frequency distribution for 1-hour SO_2 concentrations at station 3

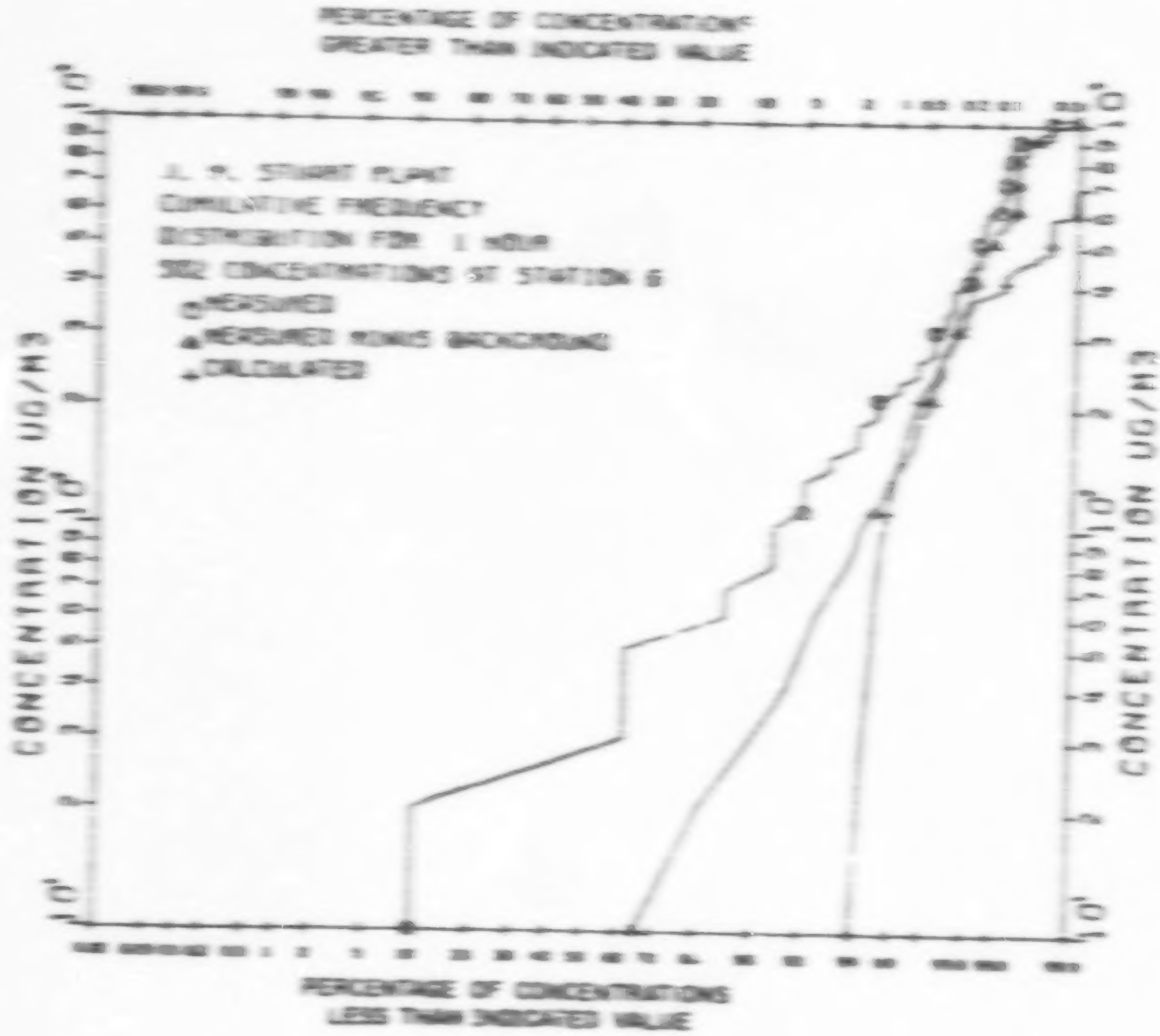

Figure F1. J. M. Stuart plant cumulative frequency distribution for 1-hour SO_2 concentrations at station 6

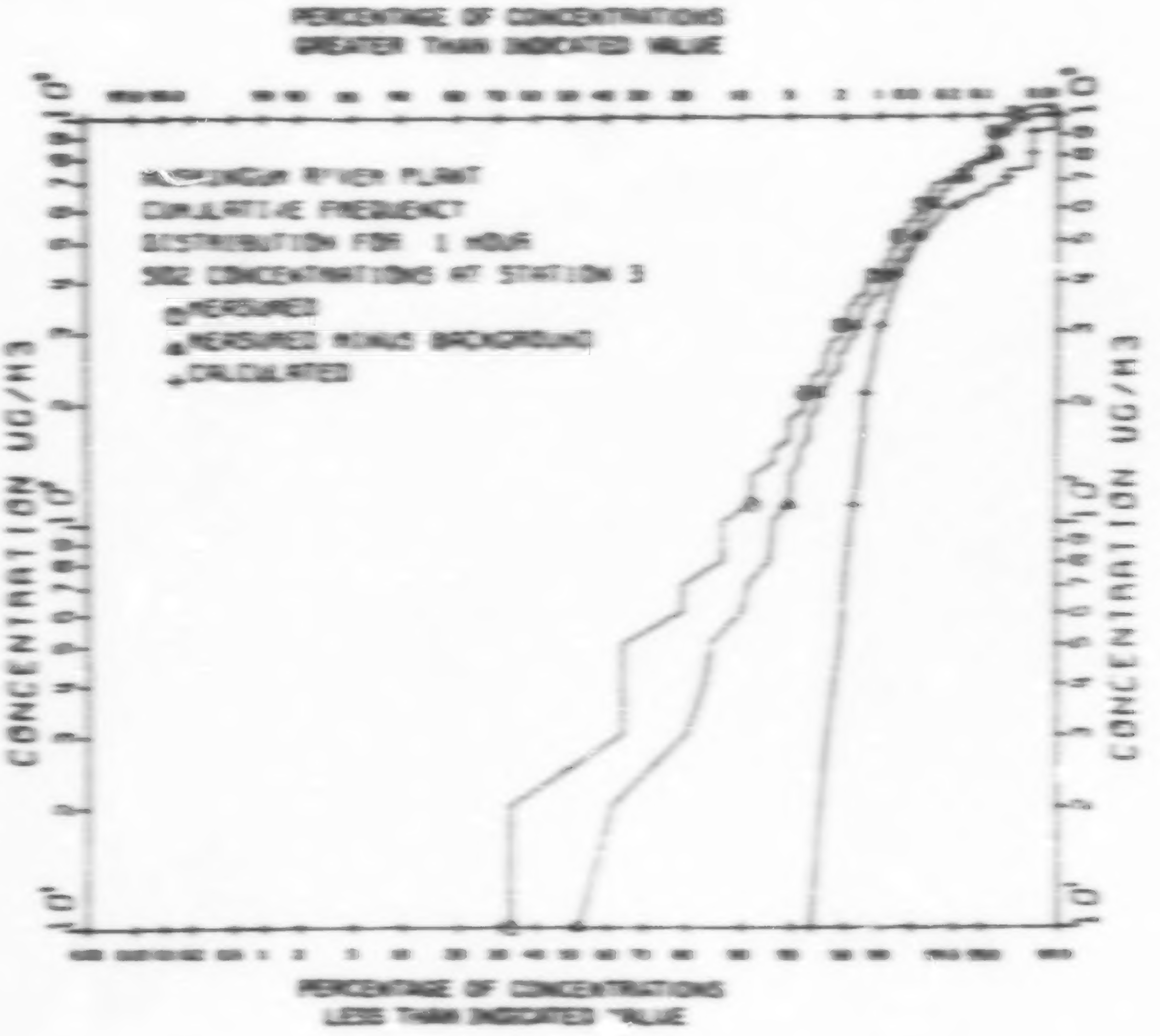

Figure 11. Muskingum River plant cumulative frequency distribution for 1-hour SO_2 concentrations at station 3

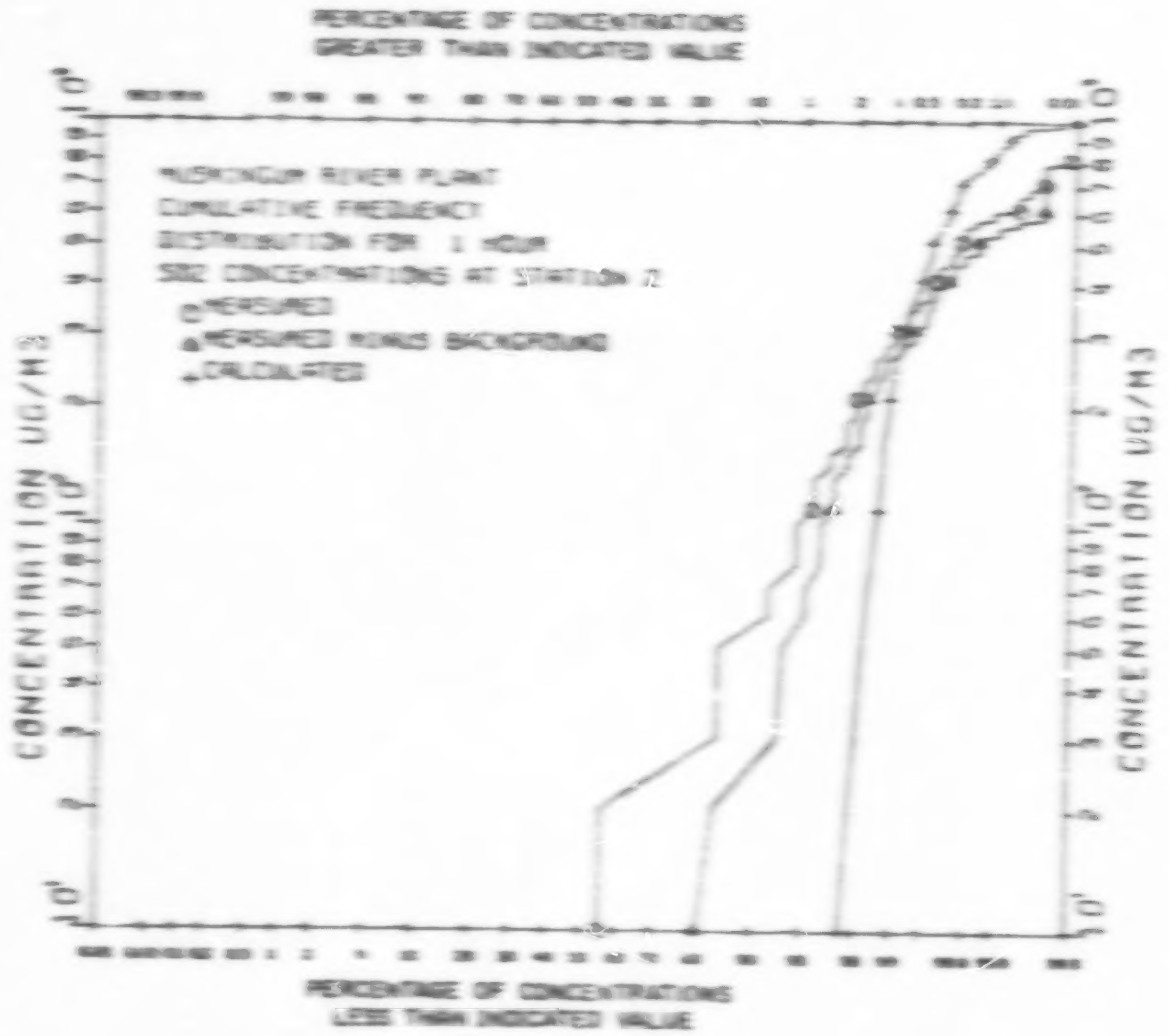

Figure 12. Muskingum River plant cumulative frequency distribution for 1-hour SO_2 concentrations at station 2

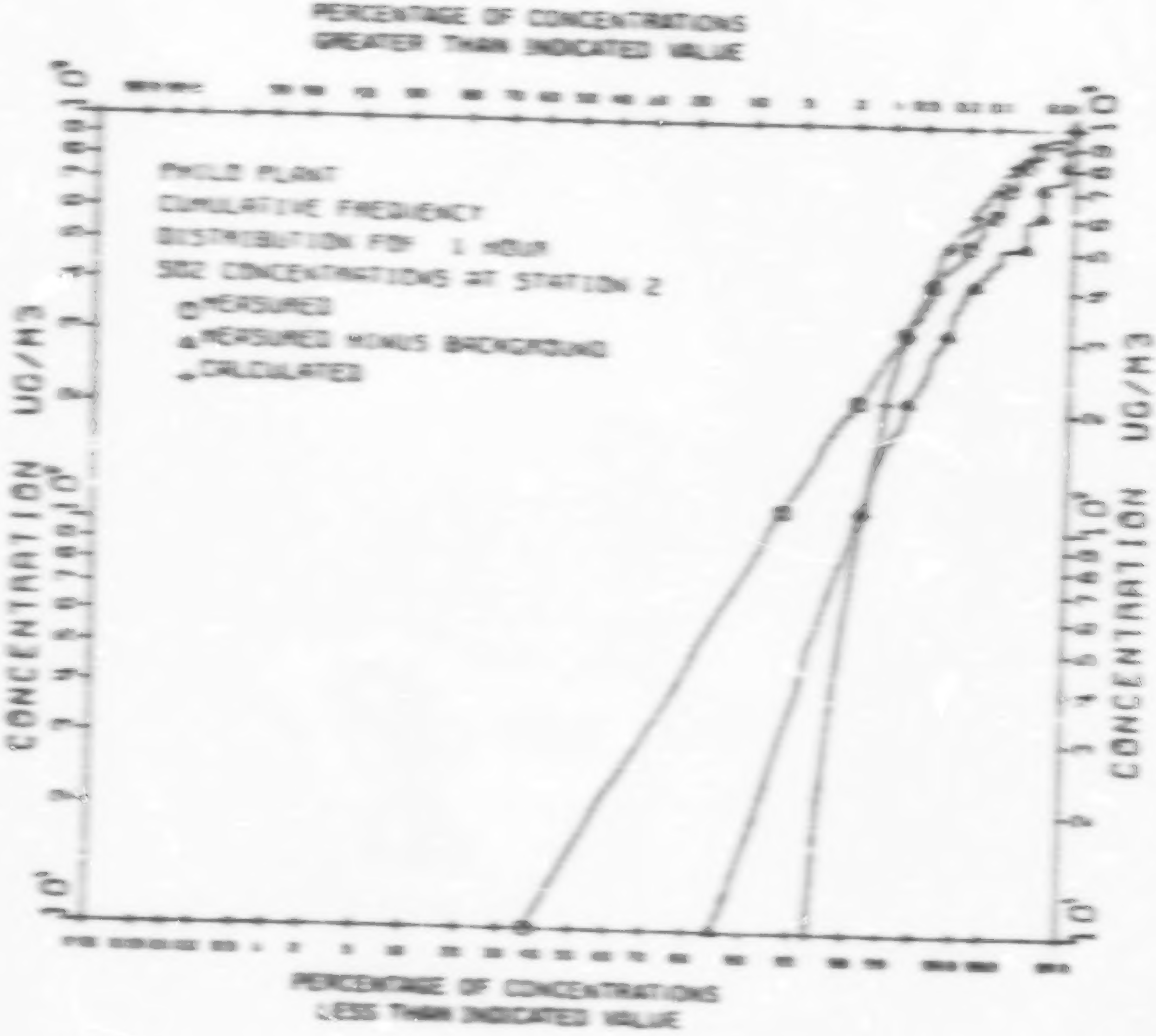

Figure 11. Philo plant cumulative frequency distribution for 1-hour SO_2 concentrations at station 2

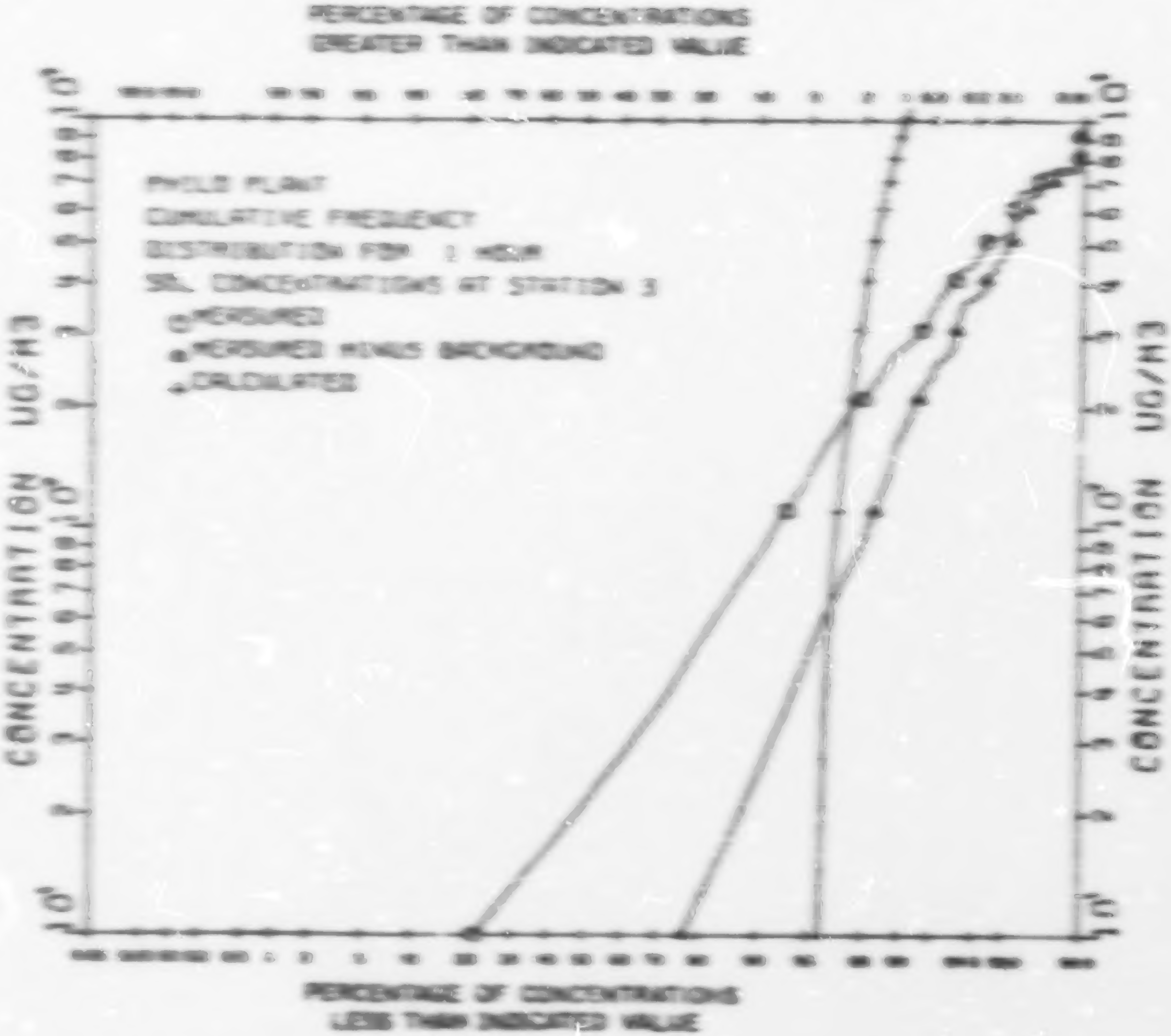

Figure [illegible]. Philo plant cumulative frequency distribution for 1-hour SO_2 concentrations at station 3

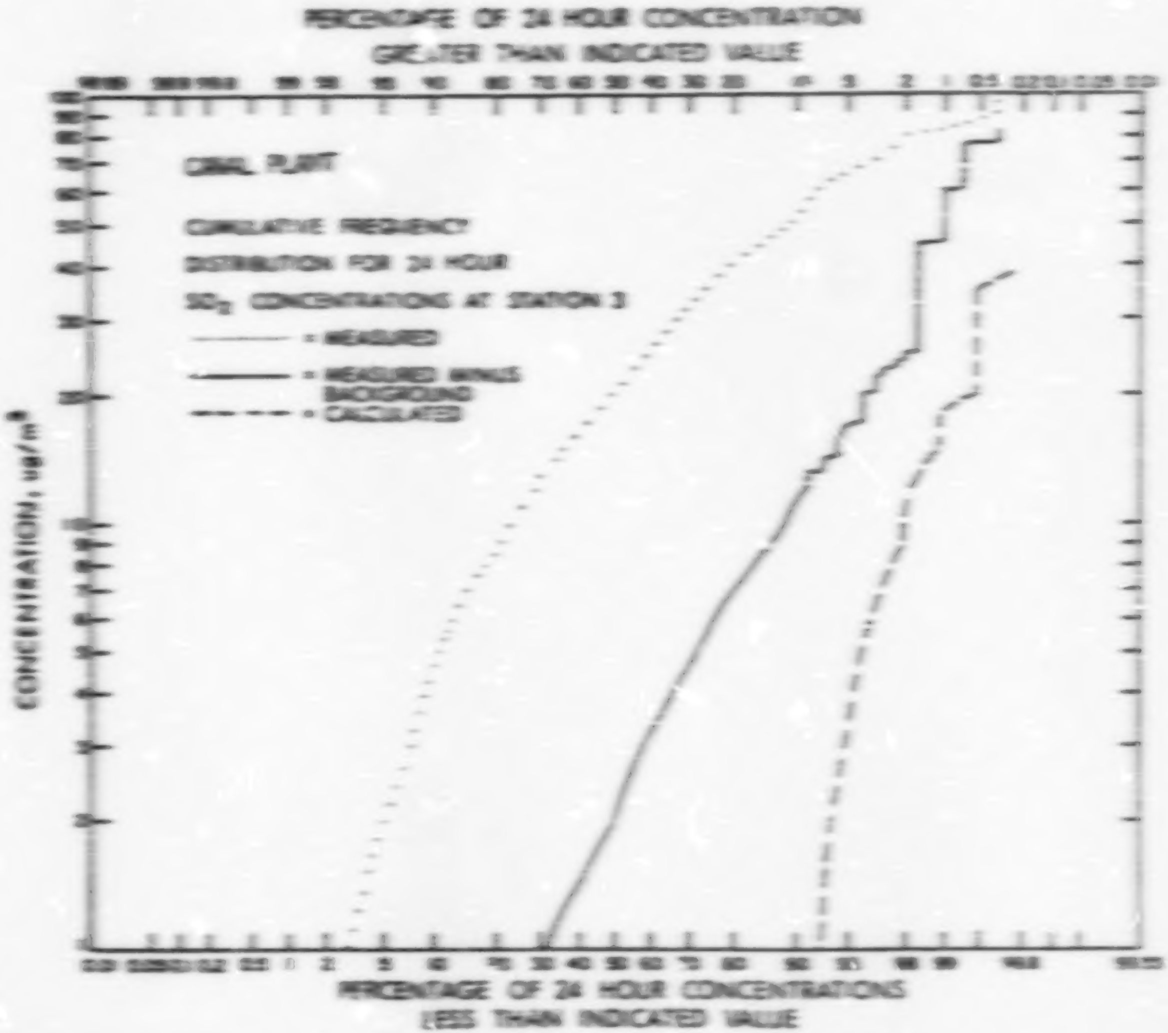

Figure 35. Cumulative frequency distribution for 24 hour SO_2 concentrations at station 3

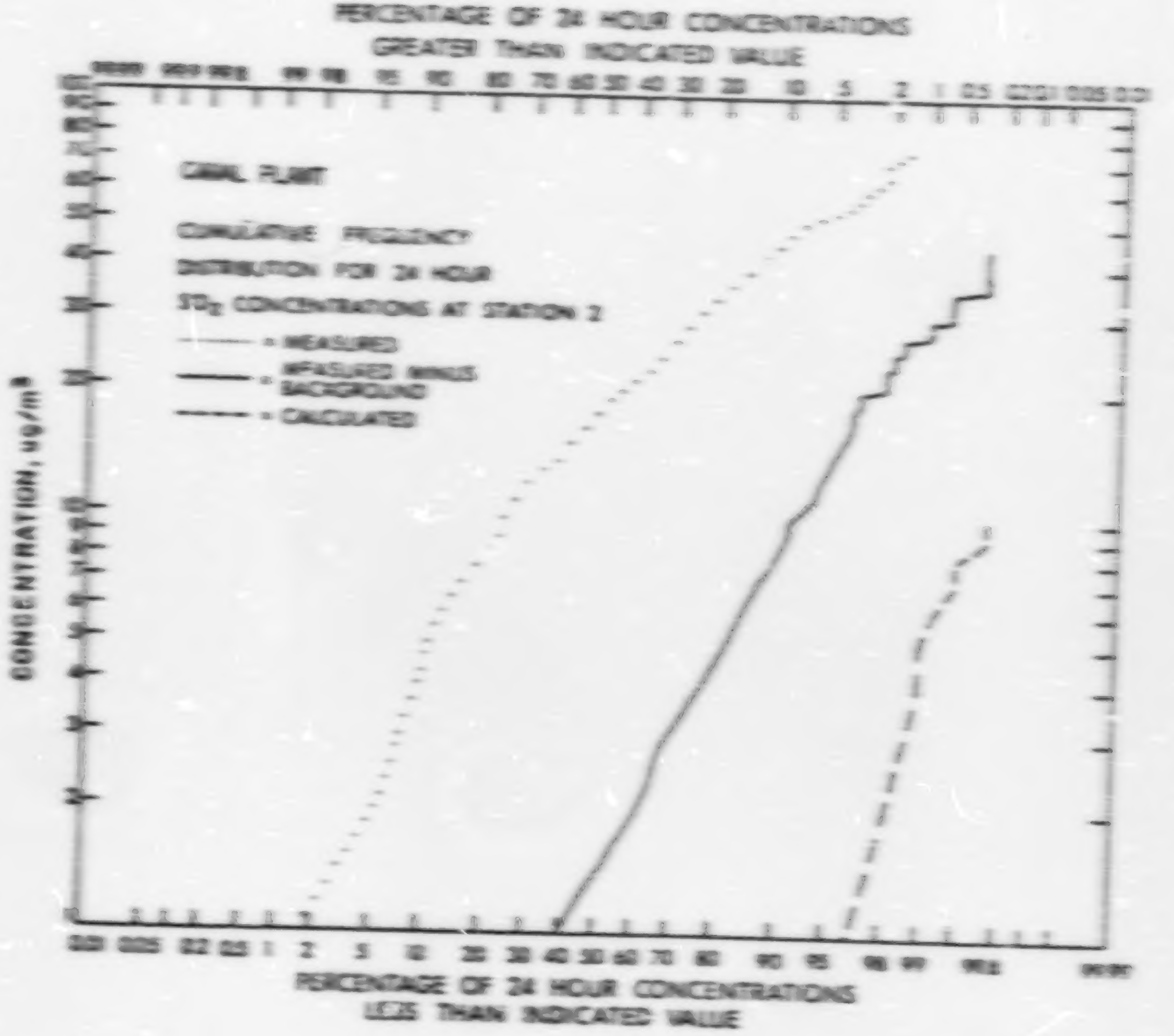

Figure 15. Cumulative frequency distribution for 24 hour SO_2 concentrations at station 2

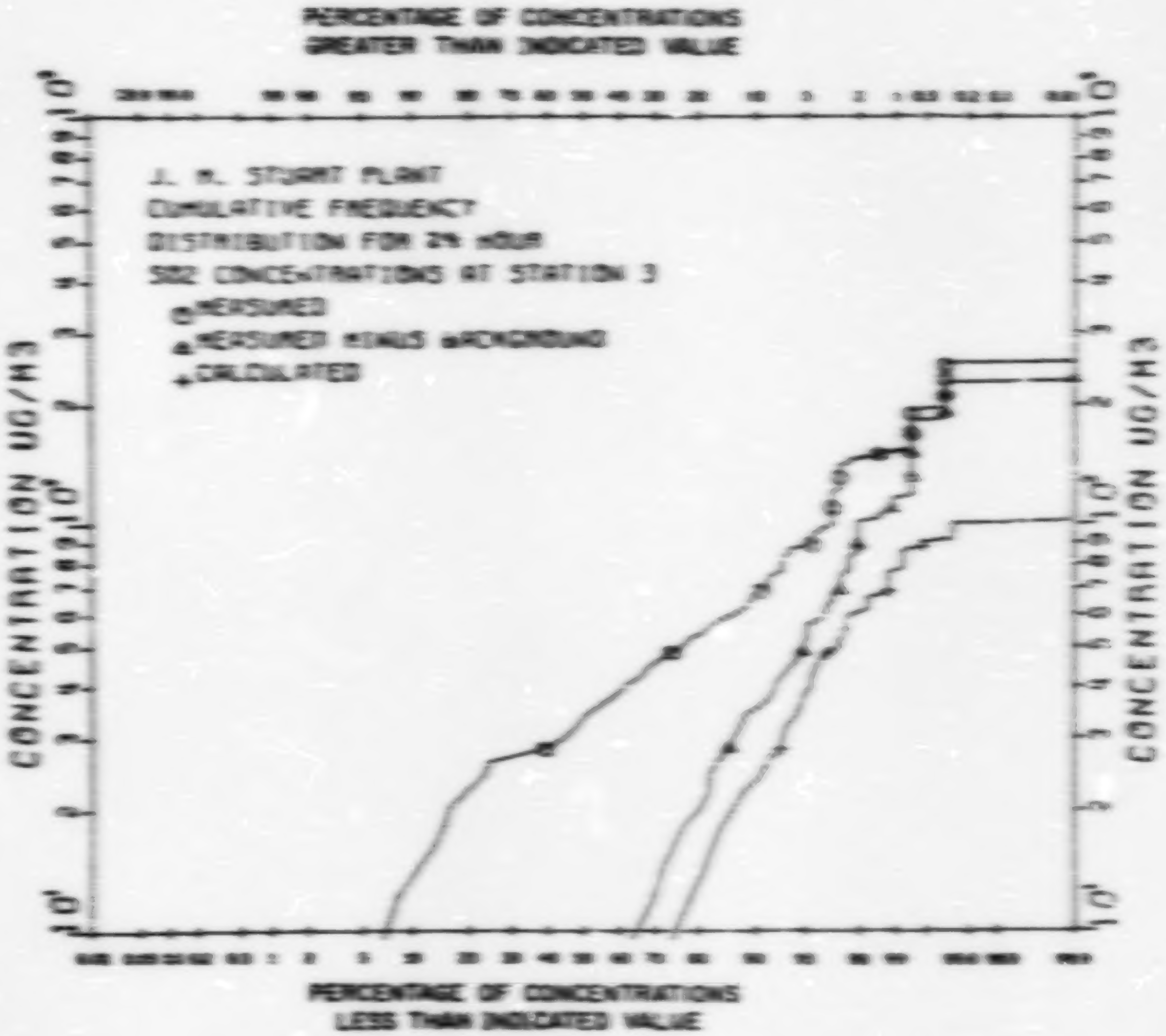

Figure 17. J. M. Stuart plant cumulative frequency distribution for 24-hour SO_2 concentrations at station 3

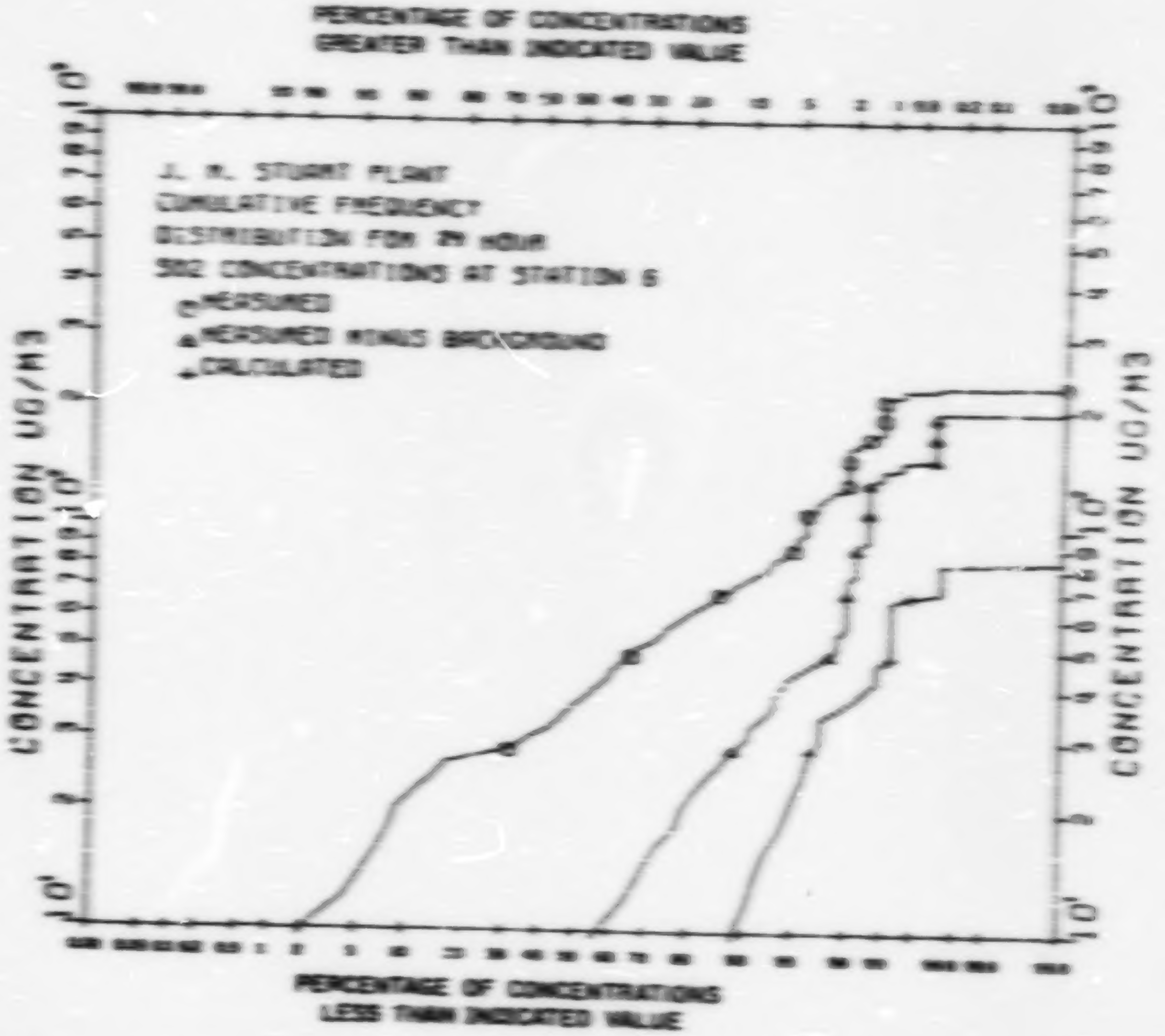

Figure 18. J. M. Stuart plant cumulative frequency distribution for 24-hour SO_2 concentrations at station 6

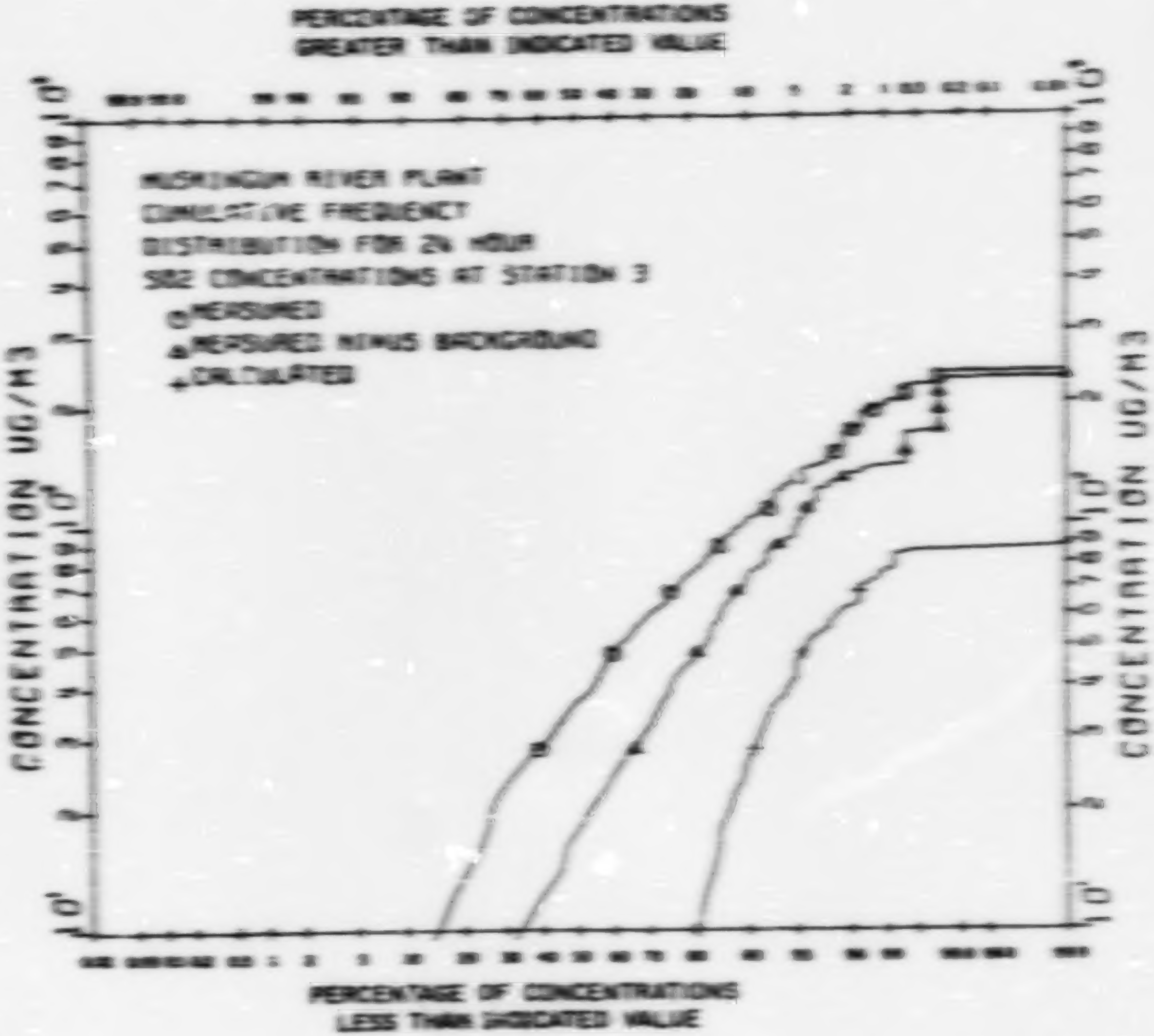

Figure 19. Muskingum River plant cumulative frequency distribution for 24-hour SO_2 concentrations at station 3

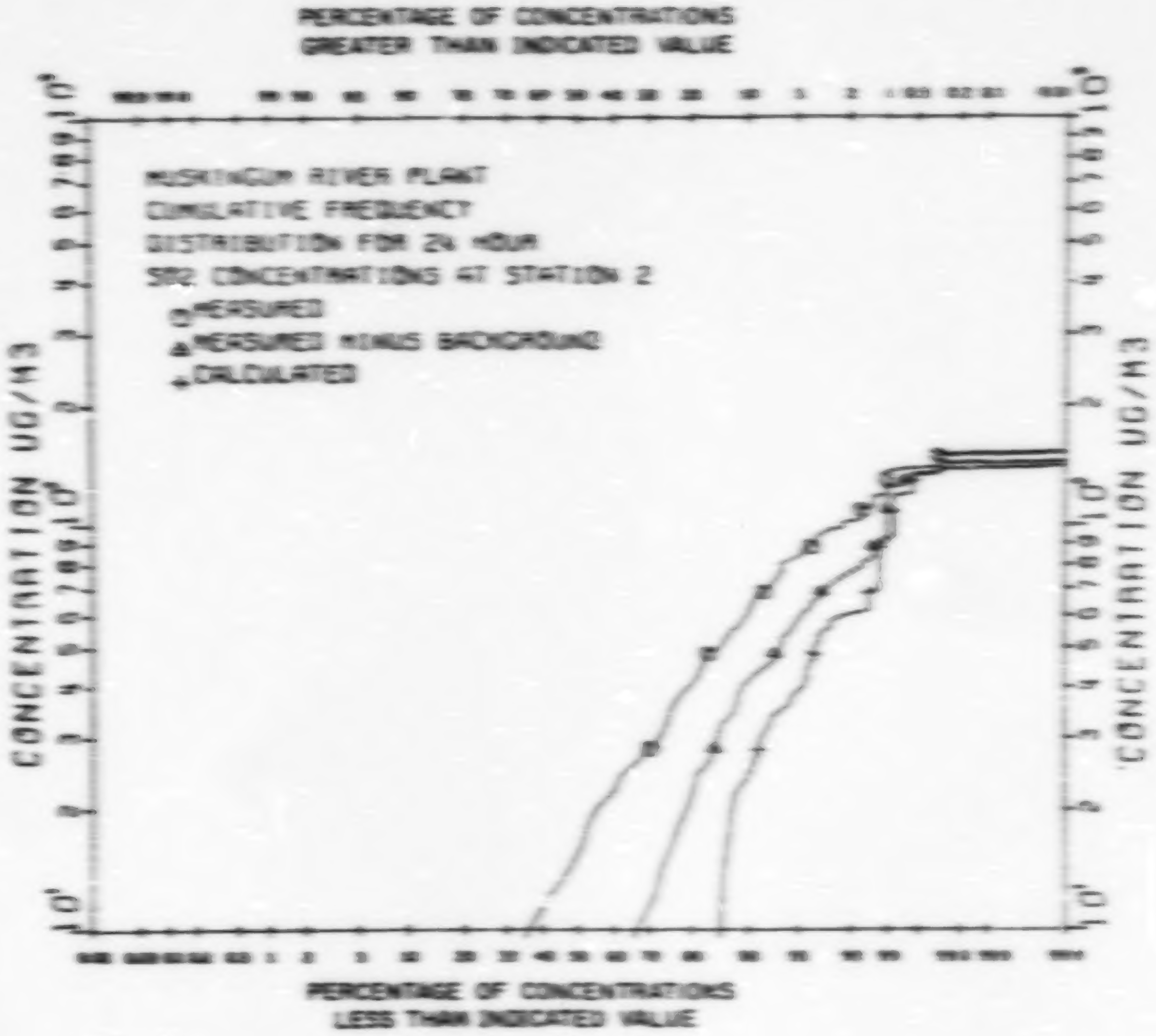

Figure 28. Muskingum River plant cumulative frequency distribution for 24-hour SO_2 concentrations at station 2

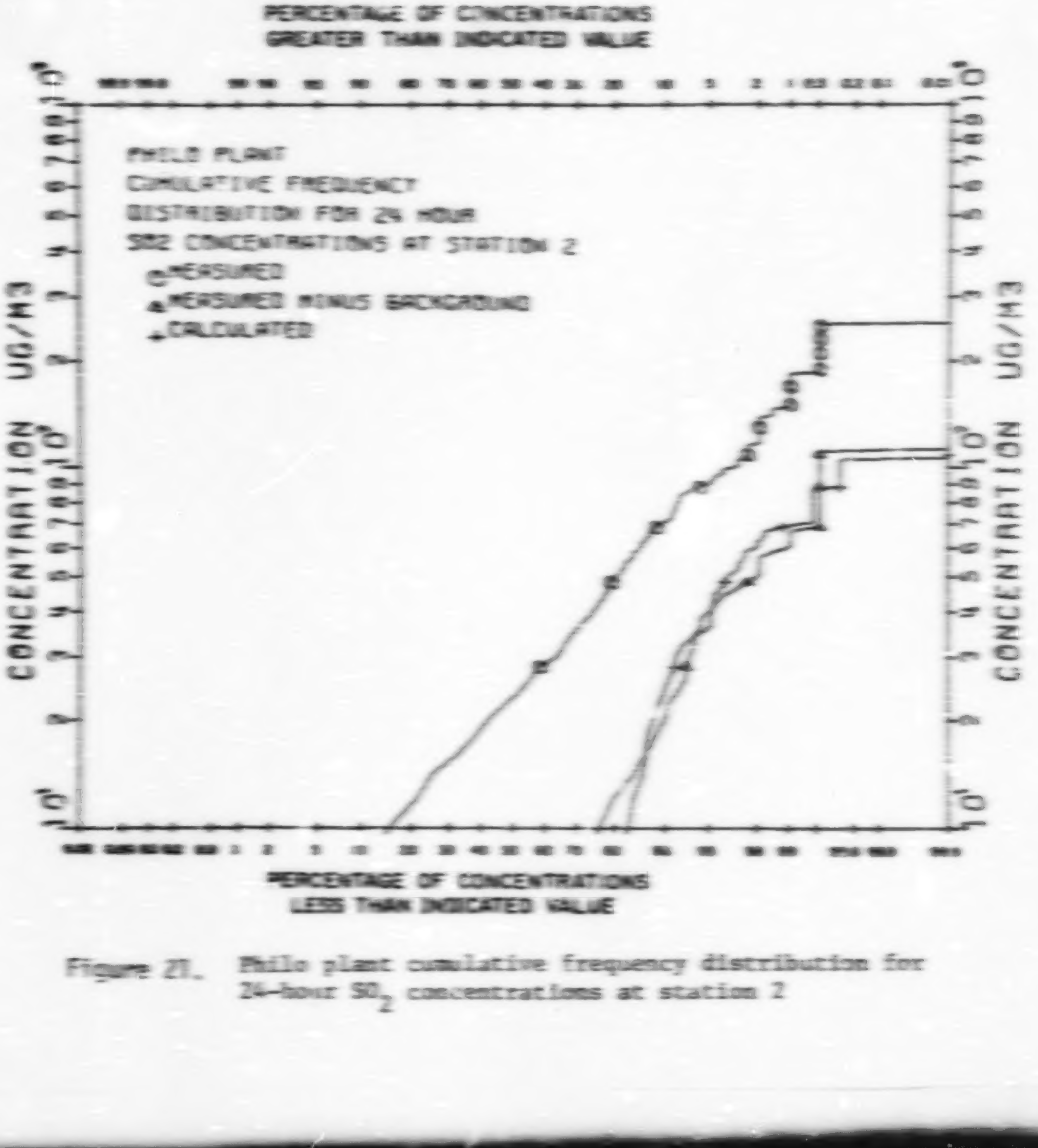

Figure 21. Philo plant cumulative frequency distribution for 24-hour SO_2 concentrations at station 2

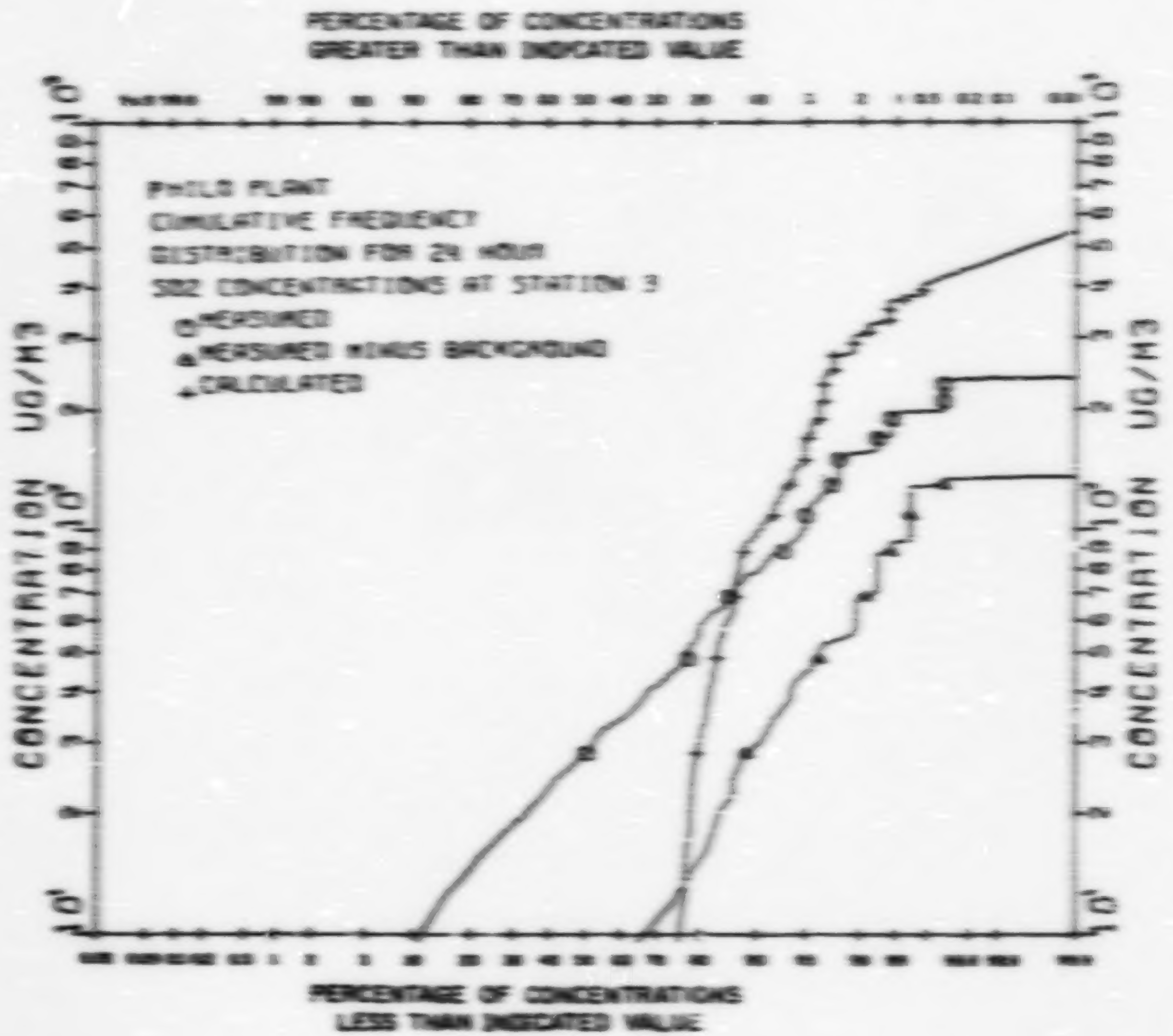

Figure 22. Philo plant cumulative frequency distribution for 24-hour SO_2 concentrations at station 3

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